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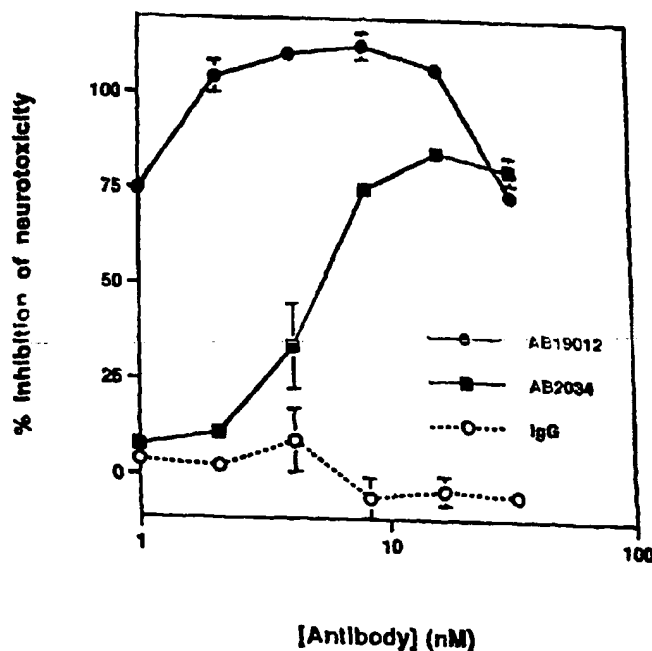
(57) Abstract: The present invention features methods and compositions for inhibiting amyloidogenic protein toxicity, inhibiting formation of an amyloidogenic protein deposit and/or treating amyloidogenic diseases by administering a pharmaceutically effective amount of one or more agents that bind an integrin or an integrin subunit.

[Antibody] (nM)

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METHODS OF INHIBITING AMYLOID TOXICITY

[001] This application claims the benefit of priority from U.S. Provisional Application No. 60/304,315, filed July 9, 2001, and U.S. Provisional Application No. 60/341,772, filed December 17, 2001, both of which are incorporated herein by reference in their entirety.

[002] Amyloidogenic proteins are involved in the pathology of multiple disease states. Diseases resulting from abnormal deposition of amyloidogenic proteins include, but are not limited to, Alzheimer's disease, type II diabetes, Parkinson's disease, diseases caused all or in part by prions (such as Creutzfeldt-Jakob disease, scrapie, and bovine spongiform encephalopathy), and amyloidoses, including both hereditary amyloidoses and systemic amyloidoses.

[003] Alzheimer's disease (AD) is a progressive neurodegenerative disease resulting in senile dementia that afflicts four million people in the United States alone (see generally Sloe, *TINS*, 16:403-409 (1993); Hardy *et al.*, WO 92/13069; Sloe, *J. Neuropathol. Exp. Neurol.*, 53:438-447 (1994); Duff *et al.*, *Nature*, 373:476-477 (1995); Games *et al.*, *Nature*, 373:523 (1995). Broadly speaking, the disease falls into two categories: late onset, which occurs in old age (65+ years); and early onset, which develops well before the senile period, *i.e.*, between 35 and 60 years. In both types of disease, the pathology is the same but the abnormalities tend to be more severe and widespread in cases beginning at an earlier age. The disease is characterized by at least two types of lesions in the brain, senile plaques and neurofibrillary tangles. Neurofibrillary tangles are intracellular deposits of microtubule associated tau protein consisting of two filaments twisted about each other in pairs. Senile plaques are areas of disorganized neuropil up to 150 microns across (visible by microscopic analysis of sections of brain tissue) and have extracellular amyloid deposits at the center. The principal component of such plaques is Aβ peptide (see Forsyth *Phys. Ther.*, 78:1325-1331 (1998)). Additional proteins found in the plaques include laminin as described by Murtomaki *et al.*, *J. Neurosci. Res.*, 32:261-273 (1992), apoE, acetylcholinesterase, and heparin sulfate proteoglycans, as described by Yan *et al.*, *Biochim. Biophys. Acta*, 1502:145-57 (2000). Aβ peptide is an internal fragment of 39-43 amino acids of a precursor protein termed amyloid precursor protein (APP). Several mutations within the APP

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protein have been correlated with the presence of Alzheimer's disease (Goate *et al.*, *Nature*, 349:704-06 (1991) (valine[717] to isoleucine); Harlin *et al.*, *Nature*, 353:844-46 (1991) (valine[717] to glycine); Murrell *et al.*, *Science*, 254:97-99 (1991) (valine[717] to phenylalanine); Mullan *et al.*, *Nature Genet.*, 1:345-47 (1992) (a double mutation changing lysine[595]methionine[596] to asparagine[595]leucine[596]). Such mutations are thought to cause Alzheimer's disease by increased or altered processing of APP to Aβ, particularly processing of APP to increased amounts of the long form of Aβ (*i.e.*, A1-42 and A1-43). Mutations in other genes, such as the presenilin genes PS1 and PS2, are thought to indirectly affect processing of APP to generate increased amounts of long form Aβ (Hardy, *TINS*, 20:154 (1997)). These observations indicate that Aβ, and particularly its long form, is a causative element in Alzheimer's disease (Velez-Pardo *et al.*, *Gen. Pharm.*, 31(5):675-81 (1998)).

[004] Almost all individuals with Down's syndrome, who have an extra copy of chromosome 21, show neuropathological changes similar to those seen in Alzheimer's disease, if they survive into their 40s. This has been attributed to excess production of beta-amyloid protein, which is encoded by the APP gene on chromosome 21.

[005] Several proteins have been investigated for possible interactions with Aβ. These include the receptor for advanced glycation endproducts, RAGE (see Yan *et al.*, *Nature*, 382:685-91 (1996)), the scavenger receptor (Khoury *et al.*, *Nature*, 382:716-719 (1996); and Paresce *et al.*, *Neuron* 17:553-65 (1996)), the endoplasmic reticulum-associated amyloid-beta biding protein (ERAB) (Yan *et al.*, *Nature*, 389:689-695 (1997)), α4 or α7 nicotinic acetylcholine receptor (Wang *et al.*, *J. Neurochem.*, 75:1155-1161 (2000) and Wang *et al.*, *J. Biol. Chem.*, 275:5626-5632 (2000)), and the low affinity p75 NGF receptor (see Yaar *et al.*, *J. Clin. Invest.*, 100:2333-2340 (1997)). Additionally, Aβ has been reported to mediate adhesion of cells in a β1-integrin subunit dependent manner when coated onto plates by Ghiso *et al.*, *Biochem. J.*, 288:1053-59 (1992); and Matter *et al.*, *J. Cell Bio.*, 141:1019-1030 (1998).

[006] In view of the number of different molecules of various functions that may interact with Aβ, the mechanism by which Aβ may mediate neurodegeneration

remains unclear. The existence and nature of other cellular proteins that may have roles in the process is also unclear.

[007] Islet amyloid has been recognized as a pathological entity in type II diabetes since the turn of the century. It has as its unique component the islet β-cell peptide, islet amyloid polypeptide (IAPP) or amylin, which is co-secreted with insulin. In addition to this unique component, islet amyloid contains other proteins, such as apolipoprotein E and the heparin sulfate proteoglycan perlecan, which are typically observed in other forms of generalized and localized amyloid. Islet amyloid is observed at pathological examination in the vast majority of individuals with type II diabetes but is rarely observed in humans without disturbances of glucose metabolism. In contrast to IAPP from rodents, human IAPP has been shown to form amyloid fibrils *in vitro*. Because all human subjects produce and secrete the amyloidogenic form of IAPP, yet not all develop islet amyloid, some other factors are likely to be involved in islet amyloid formation. One hypothesis is that an alteration in β-cell function resulting in a change in the production, processing, and/or secretion of IAPP is involved in the initial formation of islet amyloid fibrils in human diabetes. This formation of amyloid fibrils then allows the progressive accumulation of IAPP-containing fibrils. The eventual replacement of β-cell mass by amyloid contributes to the development of hyperglycemia.

[008] One factor that may be involved in producing the changes in the β-cell that result in the initiation of amyloid formation is the increased consumption of dietary fat. Dietary fat is known to alter islet β-cell peptide production, processing, and secretion, and studies in transgenic mice expressing human IAPP support the operation of this mechanism. Further investigation using this and other models should provide insight into the mechanisms involved in islet amyloidogenesis and allow the development of therapeutic agents that inhibit or reverse amyloid fibril formation, with the goal being to preserve β-cell function and improve glucose control in type II diabetes. *Diabetes,* 48:241-253 (1999).

[009] The transmissible spongiform encephalopathies, or prion diseases, constitute a group of transmissible, rapidly progressive, invariably fatal neurodegenerative diseases

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that can manifest as acquired, hereditary or idiopathic ("sporadic") diseases. They include Creutzfeldt-Jakob disease in humans, as well as scrapie and bovine spongiform encephalopathy (BSE) in animals, and are characterized by a long incubation period that may last up to decades after experimental or accidental transmission. The classic pathological features of prion diseases include spongiform change, gliosis, and neuronal loss. In contrast to what is typically seen in infectious diseases caused by viruses, prion diseases lack a significant inflammatory response (Prusiner, *Arch. Neurol.*, 50:1129-1153 (1953), Prusiner, *Proc. Natl. Acad. Sci. U.S.A.*, 95:13363-13383 (1998).

[010] Prion diseases have received considerable scientific attention due to the unique properties of the transmissible agent, the "prion" (Prusiner, *Science*, 216:136-144 (1982)). The infectious agent is very small and extremely resistant to treatments that destroy nucleic acids and inactivate conventional viruses (*id.*), but is susceptible to treatments that denature proteins. Attempts to purify the infectious agent yielded fractions highly enriched for a hitherto unknown protein, which has been named prion protein (PrP) (Bolton *et al.*, *Science*, 218:1309-1311 (1982); Prusiner *et al.*, *Cell*, 38:127-134 (1983); Oesch *et al.*, *Cell*, 40:735-746 (1985)). No agent-specific nucleic acid has been found in these preparations (Kellings *et al.*, *J. Gen. Virol.*, 73:1025-1029 (1992); Riesner *et al.*, *Dev. Biol. Stand.*, 80:173-181 (1993)); rather, the prion protein is encoded in the host genome (Oesch *et al.*, *Cell*, 40:735-746 (1985); Chesebro *et al.*, *Nature*, 315:331-333 (1985); Basler *et al.*, *Cell*, 46:417-428 (1986)). In the brains of affected individuals, a pathognomonic accumulation of a specific disease-associated isoform of the prion protein, termed PrP^{Sc}, is found (Fig. 1). PrP^{Sc} is derived through an ill-defined post-translational process involving conformational changes from the normal cellular isoform of the prion protein (PrP^{C}) (Prusiner, *Proc. Natl. Acad. Sci. U.S.A.*, 95:13363-13383 (1998)). PrP^{C} and PrP^{Sc} have the same amino acid sequence (Stahl *et al.*, *Biochemistry*, 32:1991-2002 (1993)), however, they differ in conformation. PrP^{Sc} can be distinguished from PrP^{C} by its high content of β-sheet structures (Pan *et al.*, *Proc. Natl. Acad. Sci. U.S.A.*, 90:10962-10966 (1993)), its tendency to form large aggregates, and its partial resistance to digestion with proteinase K.

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[011] Hereditary amyloidoses comprise a clinically and genetically heterogeneous
group of autosomal dominant inherited diseases characterized by the deposit of
insoluble protein fibrils in the extracellular matrix. These diseases typically present
symptoms of polyneuropathy, carpal tunnel syndrome, autonomic insufficiency,
cardiomyopathy, and gastrointestinal features, occasionally accompanied by vitreous
opacities and renal insufficiency. Other phenotypes are characterized by nephropathy,
gastric ulcers, cranial nerve dysfunction, and corneal lattice dystrophy. Rarely, the
leptomeningeal or cerebral structures are also involved in the clinical picture. The age
at onset is as early as 17 and as late as 78 years. The basic constituents of amyloid
fibrils are physiologic proteins that have become amyloidogenic through genetically
determined conformation changes. Mutated transthyretin (TTR), formerly termed
prealbumin, is the most frequent offender in hereditary amyloidosis. Orthotopic liver
transplantation (OLT) stops the progression of the disease, which is otherwise generally
fatal, by removing the main production site of the amyloidogenic protein. The
indications for OLT and its success depend on the grade of cardiovascular and
autonomic dysfunction at the time of surgery, age, comorbidity, and type of mutation.
Alternative treatment modalities with drugs stabilizing the native tetrameric
conformation of TTR and inhibiting fibril formation are currently being intensively
studied.

[012] Systemic amyloidoses are characterized by the extracellular deposit of fibrillary
protein aggregations in parenchymal organs; blood vessels; subcutaneous, submucosal,
and peritendinous fat; heart; eyes; and meninges. In addition, any part of the peripheral
nervous system may be involved, including the nerve trunks, plexuses, and the sensory
and autonomic ganglia. In the peripheral nerves, amyloid deposits occur in the epi-,
peri-, or endoneurium, usually in a patchy and localized distribution. On light
microscopy with conventional stains, amyloid deposits have a homogeneous,
eosinophilic appearance. With Congo red staining, they show a characteristic yellow-
green birefringence under polarized light.

[013] A variety of proteins are responsible for amyloid formation; in fact, a total of 18
amyloidogenic proteins have been identified in human amyloidoses. Nonhereditary

systemic amyloidoses can be caused by immunoglobulin light chains (AL-type, in plasma cell dyscrasias), fragments of serum amyloid A, an acute-phase protein (AA-type, in chronic inflammatory diseases), transthyretin (TTR; in senile systemic amyloidosis), and β_2-microglobulin (in patients with uremia and dialysis). Hereditary amyloidoses are due to genetic variants of physiologic proteins, including TTR and, much more rarely, apolipoprotein-A1, lysozyme, fibrinogen, gelsolin, amyloid-β, and cystatin C. TTR, formerly called prealbumin, is a normal tetrameric serum protein that is involved in the transport of serum thyroxine and retinal-binding protein. It is encoded by a single gene on chromosome 18, of which more than 70 autosomal dominantly inherited point mutations occurring at 51 different sites have been described. Among these, substitution of valine by methionine at position 30 (Met30) is by far the most frequent and geographically most widely disseminated.

[014] Parkinson's disease is a progressive neurological disorder marked by tremors, muscle rigidity, and balance and coordination problems. The destruction of brain cells that produce the chemical dopamine underlies these symptoms. These diseased cells are also marked by protein deposits called Lewy bodies. No one knows why the cells die or whether the Lewy bodies help kill them. Mutations in the genes for two proteins, called parkin and α-synuclein, are linked to separate, rare forms of inherited Parkinson's disease. But both parkin and α-synuclein are found in Lewy bodies that build up in the brains of all Parkinson's disease patients.

[015] Recent findings suggest that parkin plays an important role in regulating proteins associated with Lewy bodies in the brain, including α-synuclein and synphilin. Normally, parkin uses yet another protein, called ubiquitin, to "tag" other proteins for destruction. But if something goes wrong in the relationship among these proteins, this could lay the groundwork for the cell death seen in Parkinson's disease. Both parkin and α-synuclein are linked with synphilin-1 in a common pathogenic mechanism involving the ubiquitination of Lewy body-associated proteins. Dawson *et al., Nature Medicine,* 7:1144-1150 (2001). Thus, given its interaction with parkin, problems with α-synuclein may be at the core of both the inherited and common forms of Parkinson's disease. *Id.*

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SUMMARY OF THE INVENTION

[016] The invention provides methods of inhibiting formation of an amyloid deposit. The methods comprise administering an effective dosage of one or more agents that bind to a molecule selected from among:

(1) an integrin subunit selected from among α2, αv, α6, and β1;

(2) an integrin selected from among α2β1, α6β1, and αvβ1; and

(3) laminin,

under conditions such that the one or more agents inhibit the formation of an amyloid deposit.

[017] In some methods, the agent binds to the α2 integrin subunit.

[018] In some methods, the agent binds to the αv integrin subunit.

[019] In some methods, the agent binds to the β1 integrin subunit.

[020] In some methods, the agent binds to the α6 integrin subunit.

[021] In some methods, the agent binds to the integrin α2β1.

[022] In some methods, the agent binds to the integrin αvβ1.

[023] In some methods, the agent binds to the integrin α6β1.

[024] In some methods, the agent binds to laminin.

[025] In some methods, effective dosages of at least two agents that bind to at least two integrin subunits selected from among α2, α6, αv, and β1 are administered.

[026] In some methods, effective dosages of at least three agents that bind to at least three integrin subunits selected from among α2, α6, αv, and β1 are administered.

[027] In some methods, effective dosages of at least four agents that bind to the integrin subunits α2, α6, αv, and β1 are administered.

[028] In some methods, the agent is a peptide comprising an RGD (Arg-Gly-Asp) motif.

[029] In some methods, the agent is a ligand of αvβ1, α6β1, or α2β1 integrins.

[030] In some methods, the agent is fibronectin or superfibronectin (a multimeric form of fibronectin).

[031] In some methods, the agent inhibits adhesion of α2 integrin subunit-expressing cells to collagen.

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[032]   In some methods, the agent inhibits adhesion of αv integrin subunit-expressing cells to vitronectin or fibronectin.

[033]   In some methods, the agent inhibits adhesion of β1 integrin subunit-expressing cells to fibronectin.

[034]   In some methods, the agent inhibits adhesion of αv integrin subunit-expressing cells to osteopontin.

[035]   In some methods, the agent inhibits adhesion of α6 integrin subunit-expressing cells to osteopontin.

[036]   In some methods, the agent is a monoclonal or polyclonal antibody.

[037]   In some methods, the antibody recognizes the same epitope as an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

[038]   In some methods, the antibody is selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

[039]   In some methods, the agent competes for binding to the integrin α2β1 or αvβ1 with an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

[040]   In some methods, the agent is a human antibody.

[041]   In some methods, the agent is a humanized antibody.

[042]   In some methods, the antibody is a mouse antibody.

[043]   In some methods, the antibody is a polyclonal antibody.

[044]   In some methods, the antibody is a monoclonal antibody.

[045]   In some methods, the agent is an antibody fragment.

[046]   In some methods the agent comprises one or more heavy chains, light chains, F(ab), F(ab)₂, F(ab)c, or F(v) of an antibody.

[047]   In some methods, the isotype of the antibody is IgG1 or IgG4.

[048]   In some methods, the isotype of the antibody is IgG2 or IgG3.

[049]   In some methods, the agent is an antibody chain.

[050]   In some methods, the antibody comprises two pairs of light and heavy chains.

[051]   In some methods, the dosage of antibody is about 0.01 to about 10 mg/kg body weight of the patient.

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[052] In some methods, the agent is administered with a carrier as a pharmaceutical composition.

[053] In some methods, the agent is administered intraperitoneally, orally, intranasally, subcutaneously, intrathecally, intramuscularly, topically or intravenously.

[054] The invention further provides methods of inhibiting amyloid toxicity. These methods comprise administering an effective dosage of one or more agents that bind to a molecule selected from among:

    (1) an integrin subunit selected from among α2, αv, α6, and β1;

    (2) an integrin selected from among α2β1, α6β1, and αvβ1; and

    (3) laminin,

under conditions such that the one or more agents inhibit amyloid toxicity.

[055] The invention further provides methods of screening agents for activity in preventing amyloid plaque deposition. These methods comprise contacting a population of cells with an agent, contacting the population with one or more amyloid peptides (e.g., Aβ or amylin), and monitoring formation of an amyloid deposit. A reduction in the rate or extent of amyloid deposit formation indicates that the agent has activity.

[056] In some methods, the population is contacted with the agent before the amyloid peptide.

[057] The invention further provides compositions comprising an agent that binds to a molecule selected from among:

    (1) an integrin subunit selected from among α2, α6, αv, and β1;

    (2) an integrin selected from among α2β1, α6β1, and αvβ1; and

    (3) laminin,

    and a pharmaceutically acceptable carrier.

[058] In some compositions, the agent binds to the α2 integrin subunit.

[059] In some compositions, the agent binds to the αv integrin subunit.

[060] In some compositions, the agent binds to the β1 integrin subunit.

[061] In some compositions, the agent binds to the α6 integrin subunit.

[062] In some compositions, the agent binds to the integrin α2β1.

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[063] In some compositions, the agent binds to the integrin α6β1.

[064] In some compositions, the agent binds to the subunit αvβ1.

[065] In some compositions, the agent binds to laminin.

[066] Some compositions comprise effective dosages of at least two agents that bind to at least two integrin subunits selected from among α2, α6, αv, and β1.

[067] Some compositions comprise at least three agents that bind to at least three integrin subunits selected from among α2, α6, αv, and β1.

[068] Some compositions comprise at least four agents that bind to the integrin subunits α2, α6, αv, and β1.

[069] In some compositions, the agent is a peptide comprising an RGD (Arg-Gly-Asp) motif.

[070] In some compositions, the agent is a ligand of αvβ1, α6β1, or α2β1.

[071] In some compositions, the agent is fibronectin or superfibronectin (a multimeric form of fibronectin).

[072] In some compositions, the agent inhibits adhesion of α2-expressing cells to collagen.

[073] In some compositions, the agent inhibits adhesion of αv-expressing cells to vitronectin or fibronectin.

[074] In some compositions, the agent inhibits adhesion of β1-expressing cells to fibronectin.

[075] In some compositions, the agent inhibits adhesion of αv-expressing cells to osteopontin.

[076] In some compositions, the agent inhibits adhesion of α6-expressing cells to osteopontin.

[077] In some compositions, the agent is a monoclonal or polyclonal antibody.

[078] In some compositions, the antibody recognizes the same epitope as an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

[079] In some compositions, the antibody is selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

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[080] In some compositions, the agent competes for binding to the integrin α2β1 or αvβ1 with an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

[081] In some compositions, the agent is a human antibody.

[082] In some compositions, the agent is a humanized antibody.

[083] In some compositions, the antibody is a mouse antibody.

[084] In some compositions, the antibody is a polyclonal antibody.

[085] In some compositions, the antibody is a monoclonal antibody.

[086] In some compositions, the agent is an antibody fragment.

[087] In some compositions, the agent comprises one or more heavy chains, light chains, F(ab), F(ab)$_2$, F(ab)$_c$, or F(v) of an antibody.

[088] In some compositions, the isotype of the antibody is IgG1 or IgG4.

[089] In some compositions, the isotype of the antibody is IgG2 or IgG3.

[090] In some compositions, the agent is an antibody chain.

[091] In some compositions, the antibody comprises two pairs of light and heavy chains.

[092] In some compositions, the dosage of antibody is about 0.01 to about 10 mg/kg body weight of the patient.

[093] In some compositions, the agent is administered with a carrier as a pharmaceutical composition.

[094] Some compositions are formulated for intraperitoneal, oral, intranasal, subcutaneous, intramuscular, intrathecal, topical or intravenous administration.

[095] The invention further provides methods of preventing or treating an amyloidogenic disease in a patient, comprising administering to the patient an effective dosage of one or more agents that bind to a molecule selected from among:

> (1) an integrin subunit selected from among α2, α6, αv, and β1;
>
> (2) an integrin selected from among α2β1, α6β1, and αvβ1; and
>
> (3) laminin.

[096] In some methods, the agent binds to the α2 integrin subunit.

[097] In some methods, the agent binds to the αv integrin subunit.

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[098]   In some methods, the agent binds to the β1 integrin subunit.

[099]   In some methods, the agent binds to the α6 integrin subunit.

[0100] In some methods, the agent binds to the integrin α2β1.

[0101] In some methods, the agent binds to the integrin αvβ1.

[0102] In some methods, the agent binds to the integrin α6β1.

[0103] In some methods, the agent binds to laminin.

[0104] In some methods, effective dosages of at least two agents that bind to at least two integrin subunits selected from among α2, α6, αv, and β1 are administered.

[0105] In some methods, effective dosages of at least three agents that bind to at least three integrin subunits selected from among α2, α6, αv, and β1 are administered.

[0106] In some methods, effective dosages of at least four agents that bind to the integrin subunits α2, α6, αv, and β1 are administered.

[0107] In some methods, the agent is a peptide comprising an RGD (Arg-Gly-Asp) motif.

[0108] In some methods, the agent is a ligand of αvβ1, α6β1, or α2β1 integrins.

[0109] In some methods, the agent is fibronectin or superfibronectin (a multimeric form of fibronectin).

[0110] In some methods, the agent inhibits adhesion of α2 integrin subunit-expressing cells to collagen.

[0111] In some methods, the agent inhibits adhesion of αv integrin subunit-expressing cells to vitronectin or fibronectin.

[0112] In some methods, the agent inhibits adhesion of β1 integrin subunit-expressing cells to fibronectin.

[0113] In some methods, the agent inhibits adhesion of αv integrin subunit-expressing cells to osteopontin.

[0114] In some methods, the agent inhibits adhesion of α6 integrin subunit-expressing cells to osteopontin.

[0115] In some methods, the agent is a monoclonal or polyclonal antibody.

[0116] In some methods, the antibody recognizes the same epitope as an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

[0117] In some methods, the antibody is selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

[0118] In some methods, the agent competes for binding to the integrin $\alpha 2\beta 1$ or $\alpha v\beta 1$ with an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

[0119] In some methods, the agent is a human antibody.

[0120] In some methods, the agent is a humanized antibody.

[0121] In some methods, the antibody is a mouse antibody.

[0122] In some methods, the antibody is a polyclonal antibody.

[0123] In some methods, the antibody is a monoclonal antibody.

[0124] In some methods, the agent is an antibody fragment.

[0125] In some methods the agent comprises one or more heavy chains, light chains, $F(ab)$, $F(ab)_2$, $F(ab)_c$, or $F(v)$ of an antibody.

[0126] In some methods, the isotype of the antibody is IgG1 or IgG4.

[0127] In some methods, the isotype of the antibody is IgG2 or IgG3.

[0128] In some methods, the agent is an antibody chain.

[0129] In some methods, the antibody comprises two pairs of light and heavy chains.

[0130] In some methods, the dosage of antibody is about 0.01 to about 10 mg/kg body weight of the patient.

[0131] In some methods, the agent is administered with a carrier as a pharmaceutical composition.

[0132] In some methods, the agent is administered intraperitoneally, orally, intranasally, subcutaneously, intrathecally, intramuscularly, topically or intravenously.

[0133] In some methods, the agent is a polypeptide, and the agent is administered by administering a polynucleotide encoding the polypeptide to the patient, wherein the polynucleotide is expressed in the patient.

[0134] In some methods, the patient is monitored for the amount of administered agent in the blood of the patient.

[0135] In some methods, the disease is Alzheimer's disease.

[0136] In some methods, the disease is type II diabetes.

[0137] In some methods, the disease is Parkinson's disease.

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[0138] In some methods, the disease is caused all or in part by prion infection.

[0139] In some methods, the disease is an amyloidosis such as a hereditary or systemic amyloidosis.

[0140] In some methods, the disease is Down's syndrome.

[0141] In some methods, the patient is human.

[0142] In some methods, the patient is asymptomatic.

[0143] In some methods, the patient is under 50, in others, the patient is 50 or older.

[0144] In some methods, the patient has inherited risk factors indicating susceptibility to Alzheimer's disease.

[0145] The invention further provides methods of preventing or treating an amyloidogenic disease in a patient comprising administering to the patient an effective dosage of an agent that inhibits formation of an extracellular meshwork of amyloid proteins such as Aβ or amylin.

[0146] The invention further provides methods of preventing or treating an amyloidogenic disease in a patient comprising administering to the patient an effective dosage of an agent that suppresses expression of a gene selected from among:

　　　　1) a gene encoding an integrin subunit selected from among α2, αv, α6, and β1; and

　　　　2) a gene encoding laminin.

[0147] In some methods, the agent is an antisense nucleic acid.

[0148] In some methods, the agent is a zinc finger protein.

[0149] In some methods, the agent suppresses expression of a gene encoding the α2 integrin subunit.

[0150] In some methods, the agent suppresses expression of a gene encoding the αv integrin subunit.

[0151] In some methods, the agent suppresses expression of a gene encoding the β1 integrin subunit.

[0152] In some methods, the agent suppresses expression of a gene encoding the α6 integrin subunit.

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BRIEF DESCRIPTION OF THE FIGURES

[0153] Fig. 1 illustrates the Aβ meshwork in human cortical cultures (HCC) (top) or polyethyleneimine (PEI) (bottom) coated plates.

[0154] Fig. 2 illustrates the effects of β1 integrin subunit on both Aβ meshwork formation and neurotoxicity in HCC. Fig. 2A illustrates β1 integrin subunit expression in HCC. Fig. 2B illustrates 72 hour Aβ meshwork formation in HCC in the absence (top) or presence (bottom) of the anti-β1 antibody, 1965. Fig. 2C illustrates the inhibition of neurotoxicity in HCC preincubated with β1 integrin subunit blocking antibodies. Error bars represent standard deviation from (n=3) wells.

[0155] Fig. 3A illustrates the effects of α2 and αv integrin subunits on Aβ meshwork formation and neurotoxicity in HCC. Fig. 3B illustrates 72 hour Aβ meshwork formation in HCC preincubated in the absence (top) or presence of anti-α2 (middle) or anti-αv (bottom) antibodies. Fig. 3C illustrates the neurotoxicity in HCC preincubated with β1 integrin subunit blocking antibodies.

[0156] Fig. 4 illustrates α2 and αv expression in HCC.

[0157] Fig. 5 illustrates the effects of anti-laminin antibodies in inhibiting Aβ meshwork formation and neurotoxicity. Fig. 5A illustrates 72 hour Aβ meshwork formation in HCC preincubated in the absence (top) or presence of anti-laminin antibody (bottom). Fig. 5B illustrates neurotoxicity in HCC preincubated with anti-laminin antibodies. Error bars represent standard deviation from (n=3) wells. Fig. 5C illustrates neurotoxicity in HCC preincubated with anti-collagen antibodies. Error bars represent standard deviation from (n=3) wells.

[0158] Fig. 6 illustrates activation of the Aβ signaling pathway in HCC. Fig. 6A illustrates tyrosine phosphorylation of focal adhesion kinase (Fak)-associated paxillin in Aβ treated HCC. Fig. 6B illustrates tyrosine phosphorylation of proline-rich tyrosine kinase (Pyk2)-associated paxillin in Aβ treated HCC.

[0159] Fig. 7 illustrates toxicity after 1 day when human cortical neurons are seeded for 1 hour followed by aspiration and treatment with soluble amylin. Integrin or integrin subunit antibodies can be added to the cells in the presence of the seed and soluble amylin to inhibit toxicity. Seed and soluble amylin alone are not toxic. However, if

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cells are seeded for 1 hour followed by aspiration and treatment with amylin, the amylin
is toxic.

[0160] Fig. 8 illustrates that integrin and integrin subunit antibodies, particularly, anti-
laminin, anti-β1, anti-αv and anti-α2 antibodies protect against amylin toxicity.

[0161] Figs. 9A and 9B illustrate the effect of integrin or integrin subunit antibodies,
including anti-αvβ3 anti-αv; and cytochalasin D, in protecting against amylin toxicity as
demonstrated by the percent inhibition of amylin 2 component toxicity after cells are
exposed for 1 hour to the seed amylin.

DEFINITIONS

[0162] Therapeutic agents of the invention are typically substantially purified from
undesired contaminants. This means that an agent is typically at least about 50% w/w
(weight/weight) purity, as well as being substantially free from interfering proteins and
contaminants. Sometimes the agents are at least about 60%, 70%, 80%, 90%, or 95%
w/w purity. Using conventional protein purification techniques, homogenous peptides
of at least 99% w/w can also be obtained.

[0163] Specific binding between two entities means an affinity of at least 10^6, 10^7, 10^8,
10^9, or
10^{10} M^{-1}. In one embodiment, affinities are greater than about 10^8 M^{-1}.

[0164] The term "antibody" or "immunoglobulin" is used to include intact antibodies
and binding fragments thereof. Typically, fragments compete with the intact antibody
from which they were derived for specific binding to an antigen fragment including
separate heavy chains, light chains Fab, Fab', F(ab')$_2$, F(ab)c, and Fv. Fragments may
be produced by recombinant DNA techniques, or by enzymatic or chemical separation
of intact immunoglobulins. The term "antibody" also includes one or more
immunoglobulin chains that are chemically conjugated to, or expressed as, fusion
proteins with other proteins. The term "antibody" also includes bispecific antibody. A
bispecific or bifunctional antibody is an artificial hybrid antibody having two different
heavy/light chain pairs and two different binding sites. Bispecific antibodies can be
produced by a variety of methods including fusion of hybridomas or linking of Fab'

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fragments (See, *e.g.*, Songsivilai and Lachmann, *Clin. Exp. Immunol.*, 79:315-321
(1990); Kostelny *et al.*, *J. Immunol.*, 148:1547-53 (1992)).

[0165] APP[695], APP[751], and APP[770] refer, respectively, to the 695, 751, and 770 amino
acid residue long polypeptides encoded by the human APP gene. See Kang *et al.*,
Nature, 325:733-36 (1987); Ponte *et al.*, *Nature*, 331:525-27 (1988); and Kitaguchi *et
al.*, *Nature*, 331:530-32 (1988). Amino acids within the human amyloid precursor
protein (APP) are assigned numbers according to the sequence of the APP[770] isoform.
Terms such as Aβ39, Aβ40, Aβ41, Aβ42, and Aβ43 refer to an Aβ peptide containing
amino acid residues 1-39, 1-40, 1-41, 1-42, and 1-43. Aβ42 has the sequence (SEQ ID
NO:1):

[0166] H2N-Asp-Ala-Glu-Phe-Arg-His-Asp-Ser-Gly-Tyr-Glu-Val-His-His-Gln-Lys-
Leu-Val-Phe-Phe-Ala-Glu-Asp-Val-Gly-Ser-Asn-Lys-Gly-Ala-Ile-Ile-Gly-Leu-Met-
Val-Gly-Gly-Val-Val-Ile-Ala-OH. Aβ41 (SEQ ID NO:3), Aβ40 (SEQ ID NO:4), and
Aβ39 (SEQ ID NO:5) differ from Aβ42 (SEQ ID NO:1) by the omission of Ala, Ala-
Ile, and Ala-Ile-Val, respectively, from the C-terminal end. Aβ43 (SEQ ID NO:2)
differs from Aβ42 (SEQ ID NO:1) by the presence of a threonine residue at the C-
terminus.

[0167] "Amylin" refers to the protein known commonly in the art or to a peptide or
polypeptide or fragment thereof, or to a precursor protein or polymer of the protein,
peptide or polypeptide. The term encompasses islet amyloid polypeptide. A
description of amylin may be found in the art in such places as Cooper *et al.*, *Proc.
Natl. Acad. Sci. U.S.A.*, 85:7763 (1988) and Leighton *et al.*, *Nature*, 335:632 (1988).

[0168] The term "amyloid peptide or protein" refers to the family of peptides and
proteins that form amyloid-like deposits, including amylin and Aβ.

[0169] The phrase "amyloid or amyloid-like deposits" includes amyloid fibrils as well
as other amyloid or amyloid-like deposits, fibrillar or nonfibrillar in structure, which are
recognized in the art as being amyloid or amyloid-like, such as deposits in senile
amyloidosis (e.g., Aβ), prion-related encephalopathies (*e.g.*, PrP), and in the kidney or
pancreas of diabetic patients (*e.g.*, amylin), *etc.* On light microscopy with conventional
stains, such deposits have a homogeneous, eosinophilic appearance. With Congo red

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staining, they show a characteristic yellow-green birefringence under polarized light.
The term also includes pre-amyloid deposits, which unlike amyloid deposits, do not
stain with Congo Red.

[0170] The term "amyloidogenic disease" is intended to encompass a disease
characterized by unwanted deposition of a protein or peptide. The term specifically
encompasses diseases characterized by unwanted deposition of amyloid peptides such
as occurs in type II diabetes (*e.g.,* amylin), Alzheimer's disease (*e.g.,* Aβ), multiple
myeloma, and rheumatoid arthritis, as described by Kahn *et al., Diabetes,* 48:241-253
(1999); and Johnson *et al., Laboratory Investigation,* 66(5):522-535 (1992). The term
also specifically encompasses diseases characterized by unwanted deposition of
amyloidogenic proteins such as Parkinson's disease or hereditary or systemic
amyloidoses as described by Hund *et al., Neurology,* 56:431-435 (2001) including those
mediated by transthyretin (TTR) deposition. Moreover, the term includes diseases
caused all or in part by infection with a prion such as Creutzfeldt-Jakob disease. Such
prion mediated diseases are characterized by accumulation of a prion protein as
described by Giese *et al., Curr. Topics Microbiology and Immunology,* 253:203-217
(2001). In short, the term is meant to include all diseases wherein the pathology is
mediated by unwanted protein or peptide deposits that adversely affect the health and
well-being of surrounding cells.

[0171] An "antigen" is an entity to which an antibody specifically binds.

[0172] The term "epitope" or "antigenic determinant" refers to a site on an antigen to
which B and/or T cells respond. B-cell epitopes can be formed both from contiguous
amino acids or noncontiguous amino acids juxtaposed by tertiary folding of a protein.
Epitopes formed from contiguous amino acids are typically retained on exposure to
denaturing solvents whereas epitopes formed by tertiary folding are typically lost on
treatment with denaturing solvents. An epitope typically includes at least 3, and more
usually, at least 5 or 8-10 amino acids in a unique spatial conformation. Methods of
determining spatial conformation of epitopes include, for example, x-ray
crystallography and 2-dimensional nuclear magnetic resonance. See, *e.g., Epitope
Mapping Protocols, in Methods in Molecular Biology,* Vol. 66, Glenn E. Morris, Ed.

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(1996). Antibodies that recognize the same or overlapping epitopes can be identified in a simple immunoassay showing the ability of one antibody to block the binding of another antibody to a target antigen.

[0173] The term "naked polynucleotide" or "naked DNA" refers to a polynucleotide not complexed with colloidal materials, *e.g.*, proteins. Naked polynucleotides are sometimes cloned in a plasmid vector.

[0174] The term "patient" includes human and other mammalian subjects that receive either prophylactic or therapeutic treatment.

[0175] Neuronal cells can be exposed to Aβ peptide as a result of the natural processing of APP to Aβ that occurs *in vivo*, or as a result of contacting the neuronal cells with a preparation of Aβ in an *in vitro* assay. Exposure to Aβ peptide can occur before, after, or at the same time as exposure to drugs.

[0176] Amyloid deposits of Aβ peptide refer to aggregates of the Aβ peptides, possibly including fibrils, that form on and around cortical cells *in vitro*, such as shown in Fig. 1A, or *in vivo*.

[0177] Unless otherwise apparent from the context, reference to fibronectin includes superfibronectin.

[0178] Competition between antibodies is determined by an assay in which the immunoglobulin under test inhibits specific binding of a reference antibody to a common antigen. Numerous types of competitive binding assays are known, for example: solid phase direct or indirect radioimmunoassay (RIA), solid phase direct or indirect enzyme immunoassay (EIA), sandwich competition assay (see Stahli *et al.*, *Methods in Enzymology*, 9:242-53 (1983)); solid phase direct biotin-avidin EIA (see Kirkland *et al.*, *J. Immunol.*, 137:3614-19 (1986)); solid phase direct labeled assay, solid phase direct labeled sandwich assay (see Harlow and Lane, "Antibodies, A Laboratory Manual," Cold Spring Harbor Press (1988)); solid phase direct label RIA using I-125 label (see Morel *et al.*, *Molec. Immunol.*, 25(1):7-15 (1988)); solid phase direct biotin-avidin EIA (Cheung *et al.*, *Virology*, 176:546-52 (1990)); and direct labeled RIA (Moldenhauer *et al.*, *Scand. J. Immunol.*, 32:77-82 (1990)). Typically, such an assay involves the use of purified antigen bound to a solid surface or cells

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bearing either an unlabelled test immunoglobulin or a labeled reference
immunoglobulin. Competitive inhibition is measured by determining the amount of
label bound to the solid surface or cells in the presence of the test immunoglobulin.
Usually the test immunoglobulin is present in excess. Antibodies identified by
competition assay (competing antibodies) include antibodies binding to the same
epitope as the reference antibody and antibodies binding to an adjacent epitope
sufficiently proximal to the epitope bound by the reference antibody for steric hindrance
to occur. Usually, when a competing antibody is present in excess, it will inhibit
specific binding of a reference antibody to a common antigen by at least 50 or 75%.

[0179] Compositions or methods "comprising" one or more recited elements may
include other elements not specifically recited. For example, a composition that
comprises antibody may contain the antibody alone or in combination with other
ingredients.

DESCRIPTION OF THE INVENTION

A.   <u>General</u>

[0180] The invention provides methods of inhibiting or preventing formation of
extracellular meshworks of amyloid proteins, such as amylin and Aβ peptide, methods
for mediating the toxic effects of such proteins, and agents for use in the methods. The
methods can be used to treat or prevent Alzheimer's disease, type II diabetes,
Parkinson's disease, systemic and hereditary amyloidoses, as well as diseases caused all
or in part by prion infection. Agents effective for use in these methods include
antibodies and other agents that bind to an integrin subunit such as β1, α2, α6, or αv.
These subunits associate as heterodimeric receptors to form integrins, *e.g.*, α2β1, α6β1,
and αvβ1. The above agents can be used individually or in combinations to inhibit
interaction between integrins and the Aβ peptide. Use of an agent or agents that inhibit
interactions between both αvβ1 and α2β1 integrins and Aβ is preferred. Fibronectin, a
ligand of integrin, αvβ1, can also be used as an agent, as can antibodies to laminin, a
ligand of αvβ1 in the above methods.

[0181] The invention is premised, in part, on the observation that antibodies to α2, αv,
α6 and β1 integrin subunits inhibit formation of extracellular meshworks of amyloid

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proteins, such as amylin and Aβ peptide. Thereby, such antibodies inhibit the toxicity of amyloid proteins. The αvβ1 ligand, fibronectin, also inhibits meshwork formation. The α2β1 ligand, laminin, does not inhibit meshwork formation but antibodies to laminin do inhibit meshwork formation and toxicity.

B.   Integrins

[0182] Integrins are a superfamily of cell surface adhesion heterodimeric transmembrane receptors, which control the attachment of cells both to the extracellular matrix and to other cells. Adhesion provides anchorages and signals for growth, migration, and differentiation. Integrins are formed by the association of one of about fifteen known alpha chains with one of about eight known beta chains. All human cells but erythrocytes express one or more integrins.

[0183] Integrin subunits α2, αv, α6 and β1 are all well known. Exemplary human sequences are retrievable from GenBank accession numbers AF062039, M14648, X59512 and X07979, respectively. Unless otherwise indicated, reference to α2, αv, α6, β1 includes these exemplary sequences, allelic variants thereof, and cognate variants from other species. Induced variants of these sequences, having sufficient sequence identity to the natural sequence to compete with the natural sequence for specific binding to a ligand of the natural sequence, can also be used in some methods. Integrins containing αv and one of the β subunits β1, β3, β5, β6 or β8 recognize ligands bearing an RGD motif, but the binding specificity varies depending on which β subunit is present. αvβ1 is known to recognize vitronectin (GenBank accession number X03168), fibronectin (GenBank accession number M26179) and osteopontin (GenBank accession number J04765). Fibronectin is a large multidomain glycoprotein found in connective tissue, on cell surfaces, and in plasma and other body fluids. Fibronectin acts with a variety of macromolecules, including components of the cytoskeleton and the extracellular matrix, circulating components involved in the blood clotting response, fibrinolytic, acute phase and complement systems, and with cell-surface receptors on a variety of cells including fibroblasts, neurons, phagocytes, and bacteria.

[0184] Integrins containing α2 and β1 subunits are known as VLA-2 (very late activation antigen 2), GPIa-IIa (glycoprotein Ia-IIa on platelets), and ECMRII

(extracellular matrix receptor II). The α2β1 integrins bind collagen-I to VI, laminin and possibly fibronectin. The receptor is expressed on B and T lymphocytes, platelets, fibroblasts, endothelial cells, and melanoma cells, and specifically recognizes collagen and laminins as ligands. Laminins are large, multi domain proteins with a common structural organization. Laminin molecules have alpha, beta, and gamma chain subunits joined together though a coiled coil domain. At least five alpha chains, two beta chains, and three gamma chains are known, and at least twelve laminins having different combinations of these chains have been reported (WO 00/66730). Laminin is found in extracellular matrices including plaques in Alzheimer's disease (Murtomaki, *et al., J. Neuro. Res.*, 32:261-73 (1992); Bronfinan, *et al., Int. J. Exp. Clin. Invest.*, 5:16-23 (1997); and Castillo, *et al., J. Neuro. Res.*, 62:451-62 (2000)). Collagen is the most abundant protein in mammals and is the main fibrous component of skin, bone, tendon, cartilage, and teeth. There are more than 23 known collagen genes (Adams *et al., Am. J. Respir. Cell. Molec. Biol.*, 1:161-168 (1989)).

[0185] The α6/β1 integrin is expressed on platelets, lymphocytes, monocytes, thymocytes, and epithelial cells, on which it functions as a laminin receptor for laminin-1, laminin-2, and laminin-4 *in vivo*. It is also a receptor for laminin-5, but not *in vivo*. For laminin-1, the binding site has been localized in the E8 domain of this extracellular matrix molecule. This receptor is also known as very late activation antigen 6 (VLA-6) and glycoprotein Ic-IIa (GPIc-IIa on platelets).

[0186] Integrins are an example of a larger class of proteins known as adhesion proteins that also includes selectins and immunoglobulin (Ig) superfamily members (*see* Springer, *Nature*, 346:425 (1990); Osborn, *Cell*, 62:3 (1990); Hynes, *Cell*, 69:11 (1992), which are incorporated by reference in their entirety for all purposes). Antibodies and other agents that bind to adhesion proteins or their ligands, and/or block interaction between the two, can be screened for activity in preventing or inhibiting the accumulation of Aβ deposits in the methods of screening described below. Examples of other selectins and their ligands suitable for screening by the methods described below include integrins α2β5, αvβ5, α6β5, α2β6, αvβ6, and α6β6. Other ligands besides α2β1 that bind to collagen may also be screened.

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C.   Agents

[0187] Therapeutic agents of the invention include antibodies that specifically bind to α2, αv, α6, and β1 integrin subunits. Binding can be assessed either with isolated integrin subunits or fragments thereof, optionally immobilized to a solid phase, or with integrin subunits expressed on the surface of cells. Often, binding is analyzed using cells expressing a heterodimeric integrin. For example, if an agent binds to cells expressing α2β1 as the only integrin, then it can be concluded that the agent binds to α2 or β1 or to α2β1 without binding to either subunit alone. These possibilities can be distinguished by testing binding of the same agent to cells bearing a different heterodimeric integrin. For example, if the same agent specifically binds to cells bearing αvβ1 as the only integrin present, then it is likely that the agent is binding to the β1 subunit. A variety of antibodies to integrin and integrin subunits are commercially available, some of which are described in the Examples.

[0188] Monoclonal or polyclonal antibodies can be used in the methods of the invention. Preferred antibodies block interaction of these integrin subunits with one or more of their natural ligands. That is, blocking antibodies to αvβ1 block interaction of this integrin with fibronectin, osteopontin and/or vitronectin. For example, the 14D9.F8 antibody described by WO 99/37683 blocks binding of αv to fibronectin. Blocking antibodies to α2β1 block interaction of this integrin with collagen or laminin. The capacity of an antibody or other agent to block can be recognized by a simple assay in which cells expressing an integrin are tested for adhesion to a plate coated with ligand in the presence or absence of antibody (or other agent). A reduction of at least about 30%, 40%, 50%, 60%, 70%, 80%, 90%, or 100% of the amount of cells binding to the plate identifies a blocking antibody (or other agent) when the antibody is present in molar excess relative to the integrin. Further analyses of the blocking capacity of the agent to other combinations of integrin subunits can pinpoint which subunit of a heterodimeric integrin is being blocked. Binding specificity of an antibody or other agent can also be determined by a competition assay in which a test antibody competes with a reference antibody known to have the desired epitope specificity for binding to an integrin subunit or cells bearing the same. If the test and reference antibodies

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compete, then they bind to the same epitope or epitopes sufficiently proximal that binding of one antibody interferes with binding of the other. In some embodiments, transfected cells express a single type of integrin.

[0189] Some antibodies for use in the invention bind to only one type of integrin subunit. Some antibodies specifically bind to two or more integrin subunits. Some antibodies bind only when the subunits of an integrin are associated as a heterodimeric integrin. For example, some antibodies bind to $\alpha2\beta1$ without binding to either $\alpha2$ or $\beta1$ alone. Some antibodies bind to $\alpha v\beta1$ without binding to either αv or $\beta1$ alone. Some antibodies bind to subunits both in free form and when the subunit is a component of a heterodimeric integrin. Peptides and small molecules that have the same binding specificity of the above antibodies can also be used.

[0190] Other therapeutic agents for use in the invention include fibrinogen, osteopontin, vitronectin, fragments thereof, and other natural or synthetic peptides containing an RGD peptide motif that competes with fibrinogen or vitronectin for binding to $\alpha v\beta1$. Small molecule mimetics that compete with fibrinogen, vitronectin, or osteopontin for binding to $\alpha v\beta1$ can also be used. Other therapeutic agents include antibodies to laminin, and peptides and small molecules with the same binding specificity.

[0191] Candidate therapeutic agents can be evaluated by performing one or more of the following screens. Typically, agents are first evaluated for specific binding to an integrin subunit, $\alpha2$, αv, $\alpha6$, or $\beta1$, and/or a heterodimeric integrin $\alpha2\beta1$, $\alpha v\beta1$ $\alpha6\beta1$, or laminin. Suitable agents typically bind with specific affinities of at least 10^7, 10^8, 10^9 or 10^{10} M^{-1}.

[0192] Thereafter, candidates are optionally evaluated for a particular epitope specificity. This can be determined by a competition assay with a reference agent, by a functional plate blocking assay as described above, or by an epitope mapping experiment in which an antibody or other agent is evaluated by Western blotting or ELISA for its capacity to bind a series of deletion mutants of an antigen. The smallest fragment to show specific binding to the antibody or other agent defines the epitope of the antibody or other agent. Alternatively, or additionally, candidate agents are evaluated for the capacity to inhibit formation of extracellular meshworks of amyloid

peptides. Suitable agents typically reduce toxicity resulting from treatment with amyloid peptides, such as amylin or Aβ, in the presence of an agent relative to a control by at least about 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, or 100% or more.

[0193] Candidate compounds can also be tested for prophylactic and therapeutic efficacy in transgenic animals predisposed to an amyloidogenic disease. Such animals include, for example, mice bearing a 717 mutation of APP described by Games *et al.,* *supra,* and mice bearing a 670/671 Swedish mutation of APP such as described by McConlogue *et al.,* US 5,612,486; Hsiao *et al., Science,* 274:99 (1996); Sturchler-Plerrat *et al., Proc. Natl. Acad. Sci. U.S.A.,* 94:13287-92 (1997); and Borchelt *et al., Neuron,* 19:939-45 (1997). Agents showing activity in transgenic mice can then be evaluated in human clinical trials. Exemplary formats for conducting human clinical trials in Alzheimer's patients are described in WO 98/24678, which is incorporated herein by reference.

A.   Antibodies

1.   General Characteristics of Immunoglobulins

[0194] The basic antibody structural unit is known to comprise a tetramer of subunits. Each tetramer is composed of two identical pairs of polypeptide chains, each pair having one "light" (about 25 kDa) and one "heavy" chain (about 50-70 kDa). The amino-terminal portion of each chain includes a variable region of about 100 to 110 or more amino acids primarily responsible for antigen recognition. The carboxy-terminal portion of each chain defines a constant region primarily responsible for effector function.

[0195] Light chains are classified as either kappa or lambda. Heavy chains are classified as gamma, mu, alpha, delta, or epsilon, and define the antibody's isotype as IgG, IgM, IgA, IgD, and IgE, respectively. Within light and heavy chains, the variable and constant regions are joined by a "J" region of about 12 or more amino acids, with the heavy chain also including a "D" region of about 10 more amino acids. (*See generally, Fundamental Immunology* (Paul, W., Ed., 2nd ed. Raven Press, N.Y., 1989), Ch. 7 (incorporated by reference in its entirety for all purposes).

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[0196] The variable regions of each light/heavy chain pair form the antibody binding site. Thus, an intact antibody has two binding sites. Except in bifunctional or bispecific antibodies, the two binding sites are the same. The chains all exhibit the same general structure of relatively conserved framework regions (FR) joined by three hypervariable regions, also called complementarity determining regions or CDRs. The CDRs from the two chains of each pair are aligned by the framework regions, enabling binding to a specific epitope. From N-terminal to C-terminal, both light and heavy chains comprise the domains FR1, CDR1, FR2, CDR2, FR3, CDR3, and FR4. The assignment of amino acids to each domain is in accordance with the definitions of Kabat, *Sequences of Proteins of Immunological Interest* (National Institutes of Health, Bethesda, MD, 1987 and 1991), or Chothia & Lesk, *J. Mol. Biol.*, 196:901-17 (1987); Chothia *et al.*, *Nature*, 342:878-83 (1989).

2.   Production of Nonhuman Antibodies

[0197] The production of nonhuman monoclonal antibodies, *e.g.*, murine, guinea pig, primate, rabbit, or rat, can be accomplished by, for example, immunizing the animal with an integrin, subunits thereof, or fragments thereof, or with cells bearing the integrin or a subunit thereof. Laminin can also be used as an immunogen for generating antibodies to laminin. See Harlow & Lane, *Antibodies, A Laboratory Manual* (Cold Spring Harbor Press, NY, 1988, incorporated herein by reference for all purposes). Such an immunogen can be obtained from a natural source, by peptide synthesis, or by recombinant expression. Optionally, the immunogen can be administered fused or otherwise complexed with a carrier protein, as described below. Optionally, the immunogen can be administered with an adjuvant. Several types of adjuvant can be used as described below. Complete Freund's adjuvant followed by incomplete adjuvant is preferred for immunization of laboratory animals. Rabbits, goats, sheep, or guinea pigs are typically used for making polyclonal antibodies. Mice are typically used for making monoclonal antibodies. Antibodies are screened for specific binding to the intended integrin or subunit thereof, or other antigen such as laminin. Antibodies can also be screened for the capacity to block binding of an integrin to its ligand as described above. Other screening procedures described above can also be conducted.

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3.   Chimeric and Humanized antibodies

[0198] Chimeric and humanized antibodies may have the same or similar binding specificity and affinity as a mouse or other nonhuman antibody that provides the starting material for construction of a chimeric or humanized antibody. Some chimeric or humanized antibodies have affinities within a factor of 2-fold, 5-fold or 10-fold that of a mouse. Chimeric antibodies are antibodies whose light and heavy chain genes have been constructed, typically by genetic engineering, from immunoglobulin gene segments belonging to different species. For example, the variable (V) segments of the genes from a mouse monoclonal antibody may be joined to human constant (C) segments, such as IgG1, IgG2, IgG3, or IgG4. A typical chimeric antibody is thus a hybrid protein consisting of the V or antigen-binding domain from a mouse antibody and the C or effector domain from a human antibody.

[0199] Humanized antibodies have variable region framework residues substantially from a human antibody (termed an acceptor antibody) and complementarity determining regions substantially from a nonhuman antibody such as a mouse-antibody, (referred to as the donor immunoglobulin). See Queen *et al., Proc. Nat. Acad. Sci. U.S.A.,* 86:10029-33 (1989) and WO 90/07861, US 5,693,762, US 5,693,761, US 5,585,089, US 5,530,101, and Winter, US 5,225,539 (each of which are incorporated herein by reference in their entirety for all purposes). The constant region, if present, is also substantially or entirely from a human immunoglobulin. The human variable domains are usually chosen from human antibodies whose framework sequences exhibit a high degree of sequence identity with the murine variable region domains from which the CDRs were derived. The heavy and light chain variable region framework residues can be derived from the same or different human antibody sequences. The human antibody sequences can be the sequences of naturally occurring human antibodies or can be consensus sequences of several human antibodies. See Carter *et al.,* WO 92/22653. Certain amino acids from the human variable region framework residues are selected for substitution based on their possible influence on CDR conformation and/or binding to antigen. Investigation of such possible influences is by modeling,

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examination of the characteristics of the amino acids at particular locations, or empirical observation of the effects of substitution or mutagenesis of particular amino acids.

[0200] For example, when an amino acid differs between a murine variable region framework residue and a selected human variable region framework residue, the human framework amino acid should usually be substituted by the equivalent framework amino acid from the mouse antibody when it is reasonably expected that the amino acid:

(1) noncovalently binds antigen directly,

(2) is adjacent to a CDR region,

(3) otherwise interacts with a CDR region (*e.g.*, is within about 6 angstroms of a CDR region), or

(4) participates in the VL-VH interface.

[0201] Other candidates for substitution are acceptor human framework amino acids that are unusual for a human immunoglobulin at that position. These amino acids can be substituted with amino acids from the equivalent position of the donor antibody or from the equivalent positions of more typical human immunoglobulins. The variable region frameworks of humanized immunoglobulins usually show at least 85% sequence identity to a human variable region framework sequence or consensus of such sequences.

4.   Human Antibodies

[0202] Human antibodies against the above integrins or laminin are provided by a variety of techniques described below. Some human antibodies are selected by competitive binding experiments, or otherwise, to have the same epitope specificity as a particular mouse antibody, such as one of the mouse monoclonals described in the Examples. Human antibodies can also be screened for a particular epitope specificity by using only a fragment of an integrin or laminin as the immunogen, and/or by screening antibodies against a collection of deletion mutants of the integrin.

a.   Trioma Methodology

[0203] The basic approach and an exemplary cell fusion partner, SPAZ-4, for use in this approach have been described by Oestberg *et al., Hybridoma*, 2:361-67 (1983);

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Oestberg, U.S. Patent No. 4,634,664; and Engleman *et al.*, US Patent 4,634,666 (each of which is incorporated herein by reference in its entirety for all purposes). The antibody-producing cell lines obtained by this method are called triomas, because they are descended from three cells--two human and one mouse. Initially, a mouse myeloma line is fused with a human B-lymphocyte to obtain a nonantibody-producing xenogeneic hybrid cell, such as the SPAZ-4 cell line described by Oestberg, supra. The xenogeneic cell is then fused with an immunized human B-lymphocyte to obtain an antibody-producing trioma cell line. Triomas have been found to produce antibody more stably than ordinary hybridomas made from human cells.

[0204] The immunized B-lymphocytes are obtained from the blood, spleen, lymph nodes, or bone marrow of a human donor. If antibodies against a specific antigen or epitope are desired, it is preferable to use that antigen or an epitope thereof for immunization. Immunization can be either *in vivo* or *in vitro*. For *in vivo* immunization, B cells are typically isolated from a human immunized with Aβ, a fragment thereof, larger polypeptide containing Aβ or fragment, or an anti-idiotypic antibody to an antibody to A. In some methods, B cells are isolated from the same patient who is ultimately to be administered antibody therapy. For *in vitro* immunization, B-lymphocytes are typically exposed to antigen for a period of 7-14 days in a medium such as RPMI-1640 (see Engleman, *supra*) supplemented with 10% human plasma.

[0205] The immunized B-lymphocytes are fused to a xenogeneic hybrid cell such as SPAZ-4 by well known methods. For example, the cells are treated with 40-50% polyethylene glycol of MW 1000-4000, at about 37°C, for about 5-10 min. Cells are separated from the fusion mixture and propagated in medium selective for the desired hybrids (*e.g.*, containing Hypoxanthine+ Amethopterin+Thymidine (HAT Media) or Amethopterin+Hypoxanthine (AH Media)). Clones secreting antibodies having the required binding specificity are identified by assaying the trioma culture medium for the ability to bind to Aβ or a fragment thereof. Triomas producing human antibodies having the desired specificity are subcloned by the limiting dilution technique and

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grown *in vitro* in culture medium. The trioma cell lines obtained are then tested for the ability to bind Aβ or a fragment thereof.

[0206] Although triomas are genetically stable they do not produce antibodies at very high levels. Expression levels can be increased by cloning antibody genes from the trioma into one or more expression vectors, and transforming the vector into standard mammalian, bacterial, or yeast cell lines.

b.   Transgenic Non-Human Mammals

[0207] Human antibodies against integrins or laminin can also be produced from non-human transgenic mammals having transgenes encoding at least a segment of the human immunoglobulin locus. Usually, the endogenous immunoglobulin locus of such transgenic mammals is functionally inactivated. Preferably, the segment of the human immunoglobulin locus includes non-rearranged sequences of heavy and light chain components. Both the inactivation of endogenous immunoglobulin genes and the introduction of exogenous immunoglobulin genes can be achieved by the targeted homologous recombination, or by introduction of yeast artificial chromosomes (YACs). The transgenic mammals resulting from this process are capable of functionally rearranging the immunoglobulin component sequences, and expressing a repertoire of antibodies of various isotypes encoded by human immunoglobulin genes, without expressing endogenous immunoglobulin genes. The production and properties of mammals having these properties are described in detail by, *e.g.*, Lonberg *et al.*, WO93/12227 (1993); US 5,877,397, US 5,874,299, US 5,814,318, US 5,789,650, US 5,770,429, US 5,661,016, US 5,633,425, US 5,625,126, US 5,569,825, US 5,545,806, *Nature* 148, 1547-53 (1994), Fishwild *et al.*, *Nature Biotechnology*, 14, 845-51 (1996), Kucherlapati, WO 91/10741 (1991) (each of which is incorporated by reference in its entirety for all purposes). Transgenic mice are particularly suitable. Anti-integrin or anti-laminin antibodies are obtained by immunizing a transgenic nonhuman mammal, such as described by Lonberg or Kucherlapati, *supra*, with an integrin or subunit or a fragment thereof. Monoclonal antibodies are prepared by, *e.g.*, fusing B-cells from such mammals to suitable myeloma cell lines using conventional Kohler-Milstein technology. Human polyclonal antibodies can also be

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provided in the form of serum from humans immunized with an immunogenic agent. Optionally, such polyclonal antibodies can be concentrated by affinity purification using an integrin or laminin as an affinity reagent.

c.   Phage Display Methods

[0208] A further approach for obtaining human anti-integrin or anti-laminin antibodies is to screen a DNA library from human B cells according to the general protocol outlined by Huse *et al., Science,* 246:1275-81 (1989). As described for trioma methodology, such B cells can be obtained from a human immunized with an integrin, subunits, or fragments thereof, or laminin and fragments thereof. Optionally, such B cells are obtained from a patient who is ultimately to receive antibody treatment. Antibodies binding to an antigen of interest or a fragment thereof are selected. Sequences encoding such antibodies (or binding fragments) are then cloned and amplified. The protocol described by Huse is rendered more efficient in combination with phage-display technology. See, *e.g.,* Dower *et al.,* WO 91/17271 and McCafferty *et al.,* WO 92/01047, US 5,877,218, US 5,871,907, US 5,858,657, US 5,837,242, US 5,733,743, US 5,565,332, US 5,969,108, US 6,172,197 (each of which is incorporated herein by reference in its entirety for all purposes). Additional methods for selecting and labeling antibodies, or other proteins, that bind to a particular ligand are described by US 5,994,519 and US 6,180,336.

[0209] In phage display methods, libraries of phage are produced in which members display different antibodies on their outer surfaces. Antibodies are usually displayed as Fv or Fab fragments. Phage displaying antibodies with a desired specificity are selected by affinity enrichment to an integrin, subunit, or fragment thereof.

[0210] In a variation of the phage display method, human antibodies having the binding specificity of a selected murine antibody can be produced. See Winter, WO 92/20791. In this method, either the heavy or light chain variable region of the selected murine antibody is used as a starting material. If, for example, a light chain variable region is selected as the starting material, a phage library is constructed in which members display the same light chain variable region (*i.e.,* the murine starting material) and a different heavy chain variable region. The heavy chain variable

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regions are obtained from a library of rearranged human heavy chain variable regions. A phage showing strong specific binding for Aβ (*e.g.*, at least about 10^8 or at least about 10^9 M^{-1}) is selected. The human heavy chain variable region from this phage then serves as the starting material for constructing a further phage library. In this library, each phage displays the same heavy chain variable region (*i.e.*, the region identified from the first display library) and a different light chain variable region. The light chain variable regions are obtained from a library of rearranged human variable light chain regions. Again, phage showing strong specific binding for a desired integrin are selected. These phage display the variable regions of completely human anti-integrin antibodies. These antibodies usually have the same or similar epitope specificity as the murine starting material.

5.   Selection of Constant Region

[0211] The heavy and light chain variable regions of chimeric, humanized, or human antibodies can be linked to at least a portion of a human constant region. The choice of constant region depends, in part, on whether antibody-dependent complement and/or cellular mediated toxicity is desired. For example, isotypes IgG1 and IgG3 have complement activity and isotypes IgG2 and IgG4 do not. Choice of isotype can also affect passage of the antibody into the brain. Light chain constant regions can be lambda or kappa. Antibodies can be expressed as tetramers containing two light and two heavy chains, as separate heavy chains, light chains, as Fab, Fab', F(ab')$_2$, and Fv, or as single chain antibodies in which heavy and light chain variable domains are linked through a spacer.

6.   Expression of Recombinant Antibodies

[0212] Chimeric, humanized, and human antibodies are typically produced by recombinant expression. Recombinant polynucleotide constructs typically include an expression control sequence operably linked to the coding sequences of the antibody chains, including naturally-associated or heterologous promoter regions. Preferably, the expression control sequences are eukaryotic promoter systems in vectors capable of transforming or transfecting eukaryotic host cells. Once the vector has been incorporated into the appropriate host, the host is maintained under conditions suitable

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for high level expression of the nucleotide sequences and for the collection and purification of the crossreacting antibodies.

[0213] These expression vectors typically replicate in the host organisms either as episomes or as an integral part of the host chromosomal DNA. Commonly, expression vectors contain selection markers, *e.g.*, ampicillin-resistance or hygromycin-resistance, to permit detection of those cells transformed with the desired DNA sequences.

[0214] *Escherichia coli* is one prokaryotic host particularly useful for cloning the DNA sequences of the present invention. Microbes, such as yeast are also useful for expression. *Saccharomyces* is a preferred yeast host, with suitable vectors having expression control sequences, an origin of replication, termination sequences and the like as desired. Typical promoters include the 3-phosphoglycerate kinase promoter and promoters from other glycolytic enzymes. Inducible yeast promoters include, among others, the promoters from alcohol dehydrogenase, isocytochrome C, and the enzymes responsible for maltose and galactose utilization.

[0215] Mammalian cells are a preferred host for expressing nucleotide segments encoding immunoglobulins, or fragments thereof. See Winnacker, *From Genes to Clones*, (VCH Publishers, NY, 1987). A number of suitable host cell lines capable of secreting intact heterologous proteins have been developed in the art, and include CHO cell lines, various COS cell lines, HeLa cells, L cells, and myeloma cell lines. Preferably, the cells are nonhuman. Expression vectors for these cells can include expression control sequences, such as an origin of replication, a promoter, an enhancer (Queen *et al., Immunol. Rev.,* 89:49-68 (1986)), and necessary processing information sites, such as ribosome binding sites, RNA splice sites, polyadenylation sites, and transcriptional terminator sequences. Preferred expression control sequences are promoters derived from endogenous genes, cytomegalovirus, SV40, adenovirus, bovine papillomavirus, and the like. See Co *et al., J. Immunol.,* 148:1149-54 (1992).

[0216] Alternatively, antibody coding sequences can be incorporated in transgenes for introduction into the genome of a transgenic animal and subsequent expression in the

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milk of the transgenic animal (see, *e.g.*, US 5,741,957, US 5,304,489, US 5,849,992). Suitable transgenes include coding sequences for light and/or heavy chains in operable linkage with a promoter and enhancer from a mammary gland specific gene, such as casein or beta lactoglobulin.

[0217] The vectors containing the DNA segments of interest can be transferred into the host cell by well-known methods, depending on the type of cellular host. For example, calcium chloride transfection is commonly utilized for prokaryotic cells, whereas calcium phosphate treatment, electroporation, lipofection, biolistics, or viral-based transfection can be used for other cellular hosts. Other methods used to transform mammalian cells include the use of polybrene, protoplast fusion, liposomes, and microinjection. For production of transgenic animals, transgenes can be microinjected into fertilized oocytes, or can be incorporated into the genome of embryonic stem cells, and the nuclei of such cells transferred into enucleated oocytes.

[0218] Once expressed, antibodies can be purified according to standard procedures known in the art, including HPLC purification, column chromatography, gel electrophoresis, and the like (see generally, Scopes, *Protein Purification* (Springer-Verlag, NY, 1982)).

B.   Other Agents

[0219] Agents can be naturally occurring or synthetic molecules. Agents to be screened can also be obtained from natural sources, such as, *e.g.*, marine microorganisms, algae, plants, and fungi. For example, US 6,096,707, provides peptides derived from jararhagin, a metalloproteinase from the pit viper *Bothrops jararaca*. These peptides contain the amino acid motif Arg-Lys-Lys (RKK), and decrease the interaction of the human α2 β1 integrin with collagen. Alternatively, agents to be screened can be from combinatorial libraries of agents, including peptides or small molecules, or from existing repertories of chemical compounds synthesized in industry, *e.g.*, by the chemical, pharmaceutical, environmental, agricultural, marine, cosmeceutical, drug, and biotechnological industries. Agents can include, *e.g.*, pharmaceuticals, therapeutics, environmental, agricultural, or industrial

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agents, pollutants, cosmeceuticals, drugs, organic compounds, lipids, glucocorticoids, antibiotics, peptides, proteins, sugars, carbohydrates, and chimeric molecules.

[0220] A variety of methods are available for producing peptide libraries (see, *e.g.*, Lam *et al., Nature*, 354:92, 1991 and WO 92/00091; Geysen *et al., J. Immunol. Meth.*, 102:259 (1987); Houghten *et al., Nature*, 354:84 (1991); WO 92/09300; and Lebl *et al., Int. J. Pept. Prot. Res.*, 41:201 (1993)). Peptide libraries can also be generated by phage display methods. See, *e.g.*, Devlin, WO 91/18980.

[0221] Combinatorial libraries can be produced for many types of compounds that can be synthesized in a step-by-step fashion (see *e.g.*, Ellman & Bunin, *J. Amer. Chem. Soc.*, 114:10997, 1992 (benzodiazepine template), WO 95/32184 (oxazolone and aminidine template), WO 95/30642 (dihydrobenzopyran template), and WO 95/35278 (pyrrolidine template)). Libraries of compounds are usually synthesized by solid phase chemistry. However, solution-phase library synthesis can also be useful. Strategies for combinatorial synthesis are described by Dolle & Nelson, *J. Combinatorial Chemistry,* 1:235-282 (1999) (incorporated herein by reference in its entirety for all purposes). Synthesis is typically performed in a cyclic fashion with a different monomer or other component being added in each round of synthesis. Some methods are performed by successively fractionating an initial pool. For example, a first round of synthesis is performed on all supports. The supports are then divided into two pools and separate synthesis reactions are performed on each pool. The two pools are then further divided, each into a further two pools and so forth. Other methods employ both splitting and repooling. For example, after an initial round of synthesis, a pool of compounds is split into two for separate syntheses in a second round. Thereafter, aliquots from the separate pools are recombined for a third round of synthesis. Split and pool methods result in a pool of mixed compounds. These methods are particularly amenable for tagging as described in more detail below. The size of libraries generated by such methods can vary from 2 different compounds to 10^6, or 10^{10}, or any range there between.

[0222] Preparation of encoded libraries is described in a variety of publications including Needels, *et al., Proc. Natl. Acad. Sci. U.S.A.*, 90:10700 (1993); Ni, *et al., J.*

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Med. Chem., 39:1601 (1996), WO 95/12608, WO 93/06121, WO 94/08051, WO
95/35503, and WO 95/30642 (each of which is incorporated herein by reference in its
entirety for all purposes). Methods for synthesizing encoded libraries typically
involve a random combinatorial approach and the chemical and/or enzymatic
assembly of monomer units. For example, the method typically includes steps of: (a)
apportioning a plurality of solid supports among a plurality of reaction vessels; (b)
coupling to the supports in each reaction vessel a first monomer and a first tag using
different first monomer and tag combinations in each different reaction vessel; (c)
pooling the supports; (d) apportioning the supports among a plurality of reaction
vessels; (e) coupling to the first monomer a second monomer and coupling to either
the solid support or to the first tag a second tag using different second monomer and
second tag combinations in each different reaction vessel; and optionally repeating the
coupling and apportioning steps with different tags and different monomers one to
twenty or more times. The monomer set can be expanded or contracted from step to
step; or the monomer set could be changed completely for the next step (*e.g.*, amino
acids in one step, nucleosides in another step, carbohydrates in another step). A
monomer unit for peptide synthesis, for example, can include single amino acids or
larger peptide units, or both.

[0223] Compounds synthesizable by such methods include polypeptides, beta-turn
mimetics, polysaccharides, phospholipids, hormones, prostaglandins, steroids,
aromatic compounds, heterocyclic compounds, benzodiazepines, oligomeric
N-substituted glycines, and oligocarbamates. Prepared combinatorial libraries are
also available from commercial sources (*e.g.*, ChemRx, South San Francisco, CA).

[0224] Combinatorial libraries and other compounds are initially screened for
suitability by determining their capacity to bind to $\alpha2\beta1$, $\alpha6\beta1$, or $\alpha v\beta1$ integrins, or to
laminin. The additional screening procedures described above can also be used.

C.   Gene Suppression Agents

[0225] Agents that suppress gene expression can be used to suppress the expression
of genes encoding integrin subunits $\beta1$, $\alpha2$, $\alpha6$ or αv. Antisense agents can also be
used to suppress expression of certain ligands thereto, such as laminin. Suppression

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of laminin expression can achieve similar effects to treatment with antibodies against laminin. Administration of the antisense reagents of the invention to a target cell or patient results in reduced activity of one of the above integrin genes or its ligand. For general methods relating to antisense polynucleotides, see, *e.g.*, Antisense RNA and DNA, (1988), D.A. Melton, Ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, NY); Dagle *et al.*, Nucleic Acids Research, 19:1805 (1991); Uhlmann *et al.*, *Chem. Reviews*, 90:543-584 (1990). Ribozymes are another antisense agent that can suppress gene expression.

[0226] Antisense oligonucleotides can cause suppression by binding to, and interfering with the translation of sense mRNA, rendering mRNA susceptible to nuclease digestion, interfering with transcription, interfering with the processing or localization of RNA precursors, repressing the transcription of mRNA, or acting through some other mechanism. The particular mechanism by which the antisense molecule reduces expression is not critical.

[0227] Typically antisense polynucleotides comprise an antisense sequence of at least 7 to 10 to typically 20 or more nucleotides that specifically hybridize to a sequence from an mRNA of a gene. Some antisense polynucleotides are from about 10 to about 50 nucleotides in length or from about 14 to about 35 nucleotides in length. Some antisense polynucleotides are polynucleotides of less than about 100 nucleotides or less than about 200 nucleotides. In general, the antisense polynucleotide should be long enough to form a stable duplex, but short enough, depending on the mode of delivery, to administer *in vivo*, if desired. The minimum length of a polynucleotide required for specific hybridization to a target sequence depends on several factors, such as the G/C content, the positioning of mismatched bases (if any), the overall differences of the sequence relative to the population of target polynucleotides, and the chemical nature of the polynucleotide (*e.g.*, methylphosphonate backbone, peptide nucleic acid, phosphorothioate), among other factors.

[0228] Suitable conditions for hybridizing complementary nucleic acid molecules are well known to those of skill in the art. For example, hybridization under typical high stringency conditions may be performed in a mixture containing 5x SSPE, 5x Denhart

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solution, 0.5% SDS (w/v), and 100 μg/ml salmon sperm DNA. The DNA is allowed
to hybridize for a specified period of time at about 68°C. The hybridized DNA,
which is typically bound to a membrane or filter, is then washed 2 times for 10
minutes, in 2x SSPE, 0.1% SDS (w/v) at room temperature. The membrane (or filter)
is then immersed in a solution of 1 x SSPE, 0.1% SDS (w/v) for 15 minutes at 68°C,
and finally in a solution of 1x SSPE, 0.1% SDS (w/v) for 15 minutes at 68°C.

[0229] To ensure specific hybridization, the antisense sequence is at least
substantially complementary to the target mRNA or gene encoding the same. Some
antisense sequences are exactly complementary to their intended target sequence. The
antisense polynucleotides can also include, however, nucleotide substitutions,
additions, deletions, transitions, transpositions, or modifications, or other nucleic acid
sequences or non-nucleic acid moieties so long as specific binding to the relevant
target sequence corresponding to the RNA or its gene is retained as a functional
property of the polynucleotide.

[0230] Some antisense sequences are complementary to relatively accessible
sequences of mRNA (*e.g.*, relatively devoid of secondary structure). This can be
determined by analyzing predicted RNA secondary structures using, for example, the
MFOLD program (Genetics Computer Group, Madison WI) and testing *in vitro* or *in
vivo* as is known in the art. Another useful method for identifying effective antisense
compositions uses combinatorial arrays of oligonucleotides (see, *e.g.*, Milner *et al.*,
Nature Biotechnology, 15:537 (1997).

[0231] One technique to inhibit gene expression involves the introduction of double-
stranded RNA, also referred to as inhibitory RNA (RNAi), into a cell. The RNAi
comprises two complementary strands of RNA (a sense strand and an antisense
strand) annealed to each other to form a double stranded RNA molecule. The RNAi
is typically derived from an exon or coding sequence of the gene that is being targeted
for inhibition. The RNAi results in the destruction of mRNA complementary to the
sequence of the RNAi molecule. Examples of RNAi and their use in living organisms
are described, for example, by Fire *et al.*, *Nature*, 391:806-811 (1998); Nykänen *et
al.*, *Cell*, 107:309-321 (2001); and in WO 01/29058, WO 01/75164, and WO

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99/32619. In some methods the RNAi is between about 100 bp and 1000 bp, for example, about 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, or more base pairs. In some methods the RNAi is derived from an exon. In other methods, the RNAi is derived from an intron or signaling sequence.

[0232] In some methods, antisense polynucleotides have sequences in addition to the antisense sequence, including promoters and other regulatory sequences that result in expression of an antisense sequence. Provided that the promoter and, preferably termination and polyadenylation signals, are properly positioned, the strand of the inserted sequence corresponding to the noncoding strand is transcribed and acts as an antisense oligonucleotide. In some methods, the polynucleotide consists essentially of, or is, the antisense sequence. The antisense nucleic acids (DNA, RNA, modified, analogues, and the like) can be made using any suitable method for producing a nucleic acid, such as the chemical synthesis and recombinant methods disclosed herein. For example, antisense RNA molecules can be prepared by *de novo* chemical synthesis or by cloning.

[0233] Zinc finger proteins can be used as an alternative or in addition to antisense polynucleotides to suppress the expression of the genes encoding the β1, α 2, α 6 or αv integrin subunits. Zinc finger proteins can also be used to suppress the expression of certain ligands of these integrin subunits, such as laminin. Zinc finger proteins can also be used to activate or enhance the expression of other ligands, such as fibronectin, that can themselves be used as agents in the present methods. Zinc finger proteins can be engineered or selected to bind to any desired target site within a target gene. In some methods, the target site is within a promoter or enhancer. In other methods, the target site is within the structural gene. In some methods, the zinc finger protein is linked to a transcriptional repressor, such as the KRAB repression domain from the human KOX-1 protein (Thiesen *et al., New Biologist,* 2, 363-374 (1990); Margolin *et al., Proc. Natl. Acad. Sci. U.S.A.,* 91, 4509-4513 (1994)); Pengue *et al., Nucl. Acids Res.,* 22:2908-2914 (1994); Witzgall *et al., Proc. Natl. Acad. Sci. U.S.A.,* 91, 4514-4518 (1994). Preferred domains for achieving activation include the HSV VP16 activation domain (see, *e.g.,* Hagmann *et al., J. Virol.,* 71:5952-5962 (1997))

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nuclear hormone receptors (see, *e.g.*, Torchia *et al., Curr. Opin. Cell. Biol.,*
10:373-383 (1998)); the p65 subunit of nuclear factor kappa B (Bitko & Barik, *J.
Virol.,* 72:5610-5618 (1998) and Doyle & Hunt, *Neuroreport,* 8:2937-2942 (1997));
Liu *et al., Cancer Gene Ther.,* 5:3-28 (1998)), or artificial chimeric functional
domains such as VP64 (Seifpal *et al., EMBO J.,* 11:4961-4968 (1992)). Methods for
selecting target sites suitable for targeting by zinc finger proteins, and methods for
designing zinc finger proteins to bind to selected target sites are described in WO
00/00388. Methods for selecting zinc finger proteins to bind to a target using phage
display are described by EP 95908614A. Methods for using zinc finger proteins to
regulate endogenous genes are described in WO 00/00409. Zinc finger proteins can
be administered either as proteins or in the form of nucleic acids encoding zinc fingers
and having appropriate regulatory sequences.

D.   Nucleic Acids Encoding Therapeutic Agents

[0234] Antibody or other peptide reagents can be administered in the form of nucleic
acids encoding antibody chains or peptides. Such nucleic acids are typically linked to
regulatory elements, such as a promoter and enhancer, that allow expression of the
DNA segment in the intended target cells of a patient. Promoter and enhancer
elements from light or heavy chain immunoglobulin genes or the cytomegalovirus
(CMV) major intermediate early promoter and enhancer are suitable to direct
expression. In some methods promoters that cause expression in the brain are used.
Promoters such as platlet-derived growth factor (PDGF), prion, or the neural enolase
promoter are suitable.

[0235] The linked regulatory elements and coding sequences are often cloned into a
vector. For administration of double-chain antibodies, the two chains can be cloned
in the same or separate vectors.

[0236] A number of viral vector systems are available including retroviral systems
(see, *e.g.*, Lawrie and Tumin, *Curr. Opin. Genet. Develop.,* 2:102-109 (1993));
adenoviral vectors (*see, e.g.,* Bett *et al., J. Virol.,* 67:5911 (1993)); adeno-associated
virus vectors (see, *e.g.*, Zhou *et al., J. Exp. Med.,* 179:1867-75 (1994)), viral vectors
from the pox family including vaccinia virus and the avian pox viruses, viral vectors

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from the alpha virus genus such as those derived from Sindbis and Semliki Forest Viruses (*see, e.g.,* Dubensky *et al., J. Virol.,* 70:508-19 (1996)), Venezuelan equine encephalitis virus (see US 5,643,576), rhabdoviruses, such as vesicular stomatitis virus (see WO 96/34625), and papillomaviruses (Ohe *et al., Human Gene Therapy,* 6:325-33 (1995); Woo *et al.,* WO 94/12629; and Xiao & Brandsma, *Nucleic Acids. Res.,* 24:2630-22 (1996)).

[0237] DNA can be packaged into liposomes. Suitable lipids and related analogs are described by US 5,208,036, 5,264,618, 5,279,833, and 5,283,185. Vectors and DNA encoding an immunogen can also be adsorbed to or associated with particulate carriers, examples of which include polymethyl methacrylate polymers, polylactides, and poly(lactide-co-glycolides).

[0238] Gene therapy vectors or naked DNA can be delivered *in vivo* by administration to an individual patient, typically by systemic administration (*e.g.,* intravenous, intraperitoneal, nasal, gastric, intradermal, intramuscular, intrathecal, subdermal, or intracranial infusion) or topical application (*see, e.g.,* US 5,399,346). Such vectors can further include facilitating agents such as bupivacine (US 5,593,970). DNA can also be administered using a gene gun. See Xiao & Brandsma, *supra.* The DNA is precipitated onto the surface of microscopic metal beads. The microprojectiles are accelerated with a shock wave or expanding helium gas, and penetrate tissues to a depth of several cell layers. For example, the Accel™ Gene Delivery Device manufactured by Agacetus, Inc., Middleton, WI is suitable. Alternatively, naked DNA can pass through skin into the blood stream simply by spotting the DNA onto skin with chemical or mechanical irritation (see WO 95/05853).

[0239] In a further variation, nucleic acids can be delivered to cells *ex vivo,* such as cells explanted from an individual patient (*e.g.,* lymphocytes, bone marrow aspirates, tissue biopsy) or universal donor hematopoietic stem cells, followed by reimplantation of the cells into a patient, usually after selection for cells that have incorporated the vector.

IV.   Patients Amenable To Treatment

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[0240] The present methods are useful for prophylactic or therapeutic treatment of several amyloidogenic diseases and conditions that are characterized by the presence of deposits of amyloid proteins, such as amylin or Aβ peptide. Such diseases include Alzheimer's disease, Down's syndrome and cognitive impairment, type II diabetes, Parkinson's disease, amyloidoses such as hereditary or systemic amyloidoses, and diseases caused all or in part by prion infection.

[0241] Patients amenable to treatment include individuals at risk of disease but not showing symptoms, as well as patients presently showing symptoms. In the case of Alzheimer's disease, virtually anyone is at risk of suffering from Alzheimer's disease if he or she lives long enough. The present methods are especially useful for individuals who have a known genetic risk of Alzheimer's disease. Such individuals include those having relatives who have experienced this disease, and those whose risk is determined by analysis of genetic or biochemical markers. Genetic markers of risk toward Alzheimer's disease include mutations in the APP gene, for example mutations at position 717 and positions 670 and 671 referred to as the Hardy and Swedish mutations respectively (see Hardy, TINS, supra). Other markers of risk are mutations in the presenilin genes, PS1 and PS2, and ApoE4, family history of AD, hypercholesterolemia, or arteriosclerosis. Individuals presently suffering from Alzheimer's disease can be recognized from characteristic dementia, as well as the presence of the risk factors described above. In addition, a number of diagnostic tests are available for identifying individuals who have AD. These include measurement of cerebrospinal fluid (CSF) tau and Aβ42 levels. Elevated tau and decreased Aβ42 levels signify the presence of AD. Individuals suffering from Alzheimer's disease can also be diagnosed by ADRDA criteria. In asymptomatic patients, treatment can begin at any age (*e.g.*, about 10, about 20, about 30). Usually, however, it is not necessary to begin treatment until a patient reaches about 40, about 50, about 60, about 70, about 80 or about 90. Treatment typically entails multiple dosages over a period of time. In the case of Down's syndrome patients, treatment can begin prenatally by administering therapeutic agents to the mother; or treatment may begin shortly after birth.

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V.   Treatment Regimes

[0242] In prophylactic applications, pharmaceutical compositions or medicaments are administered to a patient susceptible to, or otherwise at risk of developing an amyloidogenic disease, in an amount sufficient to eliminate or reduce the risk, lessen the severity, or delay the onset of the disease, including biochemical, histological and/or behavioral symptoms of the disease, its complications and intermediate pathological phenotypes presenting during development of the disease.

[0243] In therapeutic applications, compositions or medicaments are administered to a patient suspected of, or already suffering from such a disease in an amount sufficient to cure, or at least partially arrest, the symptoms of the disease (biochemical, histological, and/or behavioral), including its complications and intermediate pathological symptoms. An amount adequate to accomplish therapeutic or prophylactic treatment is defined as a therapeutically- or prophylactically-effective dose. In therapeutic regimes, the agent is usually administered at intervals until symptoms of the disease disappear or significantly decrease. Optionally administration can be continued to prevent recurrence. In prophylactic regimes, agents are also usually administered at intervals, in some instances for the rest of a patient's life. Treatment can be monitored by assaying levels of administered agent, or by monitoring the response of the patient. The response can be monitored by ADRDA criteria and imaging of plaques in the brain of the patient (see WO 00/14810).

[0244] Effective doses of the compositions of the present invention, for the treatment of the above-described conditions vary depending upon many different factors, including means of administration, target site, physiological state of the patient, whether the patient is human or an animal, other medications administered, and whether treatment is prophylactic or therapeutic. Usually, the patient is a human; nonhuman mammals, including transgenic mammals, can also be treated. Treatment dosages are typically titrated to optimize safety and efficacy.

[0245] Dosages of antibodies, peptides, and small molecules range from about 0.0001 to about 100 mg/kg, and more usually about 0.01 to about 20 mg/kg, of the host body

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weight. For example, dosages can be about 1 mg/kg body weight or about 20 mg/kg body weight or within the range of about 1 to about 10 mg/kg. An exemplary treatment regime entails administration once per every two weeks or once a month or once every 3 to 6 months. In some methods, two, three, four or more monoclonal antibodies with different binding specificities are administered simultaneously, in which case the dosage of each antibody administered falls within the ranges indicated. For example, in some methods antibodies to two or all three of β1 integrin, α2 integrin, and αv integrin subunits are administered simultaneously. In some methods, antibodies to the α6 integrin subunit are also administered. Antibody is usually administered on multiple occasions. Intervals between single dosages can be weekly, monthly or yearly. Intervals can also be irregular as indicated by measuring blood levels of antibody to integrins in the patient. In some methods, dosage of antibody is adjusted to achieve a plasma antibody concentration of about 1 to about 1000 μg/ml, and in some methods about 25 to about 300 μg/ml. Alternatively, antibody can be administered as a sustained release formulation, in which case less frequent administration is required. Dosage and frequency vary depending on the half-life of the antibody in the patient. In general, human antibodies show the longest half life, followed by humanized antibodies, chimeric antibodies, and nonhuman antibodies. The dosage and frequency of administration can vary depending on whether the treatment is prophylactic or therapeutic. In prophylactic applications, a relatively low dosage is administered at relatively infrequent intervals over a long period of time. Some patients continue to receive treatment for the rest of their lives. In therapeutic applications, a relatively high dosage at relatively short intervals is sometimes required until the progression of the disease is reduced or terminated, and preferably until the patient shows partial or complete amelioration of the symptoms of the disease. Thereafter, the patient can be administered a prophylactic regime.

[0246] Doses for nucleic acid encoding agents range from about 10 ng to 1 g, about 100 ng to about 100 mg, about 1 μg to about 10 mg, or about 30 to about 300 μg DNA per patient. Doses for infectious viral vectors may vary from about 10 to about 100,

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or about 10^3, about 10^4, about 10^5, about 10^6, about 10^7, about 10^8, about 10^9, about 10^{10}, or more virions per dose.

[0247] Agents of the invention can be administered by parenteral, topical, intravenous, oral, subcutaneous, intrathecal, intraarterial, intracranial, intraperitoneal, intranasal, or intramuscular means for prophylactic and/or therapeutic treatment. In some methods, agents are injected directly into a particular tissue where deposits have accumulated, for example, intracranial injection. In some methods, intramuscular injection or intravenous infusion are employed for the administration of antibody. In some methods, particular therapeutic antibodies are injected directly into the cranium. In some methods, antibodies are administered as a sustained release composition or device, such as a Medipad™ device.

[0248] Agents of the invention can optionally be administered in combination with other agents that are at least partly effective in the treatment of amyloidogenic disease. In the case of Alzheimer's disease and Down's syndrome, in which amyloid deposits occur in the brain, agents of the invention can also be administered in conjunction with other agents that increase passage of the agents of the invention across the blood-brain barrier.

[0249] Agents of the invention are often administered as compositions comprising an active therapeutic agent and a variety of other pharmaceutically acceptable components. See *Remington's Pharmaceutical Science* (15th ed., Mack Publishing Company, Easton, Pennsylvania, 1980). The particular formulation employed depends on the intended mode of administration and the therapeutic application. The compositions can also include, depending on the formulation desired, pharmaceutically-acceptable, non-toxic carriers or diluents, which are defined as vehicles commonly used to formulate pharmaceutical compositions for animal or human administration. The diluent is selected so as not to negatively impact the biological activity of the combination. Examples of such diluents include, but are not limited to, distilled water, physiological phosphate-buffered saline, Ringer's solution, dextrose solution, and Hank's solution. In addition, the pharmaceutical composition

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or formulation may also include other carriers, adjuvants, or nontoxic, nontherapeutic, nonimmunogenic stabilizers, and the like.

[0250] Pharmaceutical compositions can also include large, slowly metabolized macromolecules such as proteins, polysaccharides such as chitosan, polylactic acids, polyglycolic acids, copolymers (such as latex functionalized Sepharose™ beads, agarose, cellulose, and the like), polymeric amino acids, amino acid copolymers, and lipid aggregates (such as oil droplets or liposomes).

[0251] For parenteral administration, agents of the invention can be administered as injectable dosages of a solution or suspension of the substance in a physiologically-acceptable diluent with a pharmaceutical carrier that can be a sterile liquid such as water, oils, saline, glycerol, or ethanol. Parenteral compositions for human administration are sterile, substantially isotonic, and made under GMP conditions. Additionally, auxiliary substances, such as wetting or emulsifying agents, surfactants, pH buffering substances, and the like, can be present in compositions. Other components of pharmaceutical compositions are those of petroleum, animal, vegetable, or synthetic origin, for example, peanut oil, soybean oil, and mineral oil. In general, glycols, such as propylene glycol or polyethylene glycol, are preferred liquid carriers, particularly for injectable solutions. Antibodies can be administered in the form of a depot injection or implant preparation that can be formulated in such a manner as to permit a sustained release of the active ingredient. An exemplary composition comprises monoclonal antibody at 5 mg/mL, formulated in aqueous buffer containing 50 mM L-histidine (optional), 150 mM NaCl, adjusted to a suitable pH with HCl.

[0252] Typically, compositions are prepared as injectables, either as liquid solutions or suspensions; solid forms suitable for solution in, or suspension in, liquid vehicles prior to injection can also be prepared. The preparation also can be emulsified or encapsulated in liposomes or microparticles such as polylactide, polyglycolide, or copolymer for enhanced adjuvant effect, as discussed above (see Langer, *Science,* 249:1527-33 (1990) and Hanes *et al., Advanced Drug Delivery Reviews,* 28:97-119 (1997). The agents of this invention can be administered in the form of a depot

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injection or implant preparation that can be formulated in such a manner as to permit
a sustained or pulsatile release of the active ingredient.

[0253] Additional formulations suitable for other modes of administration include
oral, intranasal, and pulmonary formulations, suppositories, and transdermal
applications. For suppositories, binders and carriers include, for example,
polyalkylene glycols or triglycerides; such suppositories can be formed from mixtures
containing the active ingredient in the range of about 0.5% to about 10%, or about 1%
to about 2%. Oral formulations include, but are not limited to, excipients such as
pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium
saccharine, cellulose, and magnesium carbonate. These compositions typically take
the form of solutions, suspensions, tablets, pills, capsules, sustained release
formulations or powders and contain about 10% to about 95% of active ingredient, or
about 25% to about 70%.

[0254] Topical application can result in transdermal or intradermal delivery. Topical
administration can be facilitated by co-administration of the agent with cholera toxin
or detoxified derivatives or subunits thereof or other similar bacterial toxins (See
Glenn *et al.*, *Nature,* 391:851 (1998)). Coadministration can be achieved by using the
components as a mixture or as linked molecules obtained by chemical crosslinking or
expression as a fusion protein. Alternatively, transdermal delivery can be achieved
using a skin patch or using transferosomes (Paul *et al.*, *Eur. J. Immunol.*, 25:3521-24
(1995); Cevc *et al.*, *Biochem. Biophys. Acta,* 1368:201-15 (1998)).

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EXAMPLES

Materials And Methods For Examples 1-5

Sources of Antibody

Antibody	Source	Antigen	Ligand blocked
MAB1998	Chemicon	human α2 integrin	collagen and laminin
MAB1950Z	Chemicon	human α2 integrin	collagen and laminin
Gi9	Immunotech	human α2 integrin	collagen
VNR147	Gibco or Chemicon	human αV integrin	fibrinogen and vitronectin
MAB1980	Chemicon	human αV integrin	vitronectin
IM1603	Immunotech	human αV integrin	vitronectin
Lia1/2	Immunotech	human ß1 integrin	fibronectin
MAB1965	Chemicon	human ß1 integrin	collagen and fibronectin
AIIB2	Caroline Damsky, UCSF	human ß1 integrin	fibronectin
AB19012	Chemicon	human laminin	laminin
AB2034	Chemicon	mouse laminin	laminin

Tissue culture

[0255] Tissue culture plates were coated with polyethyleneimine (PEI) in 150 mM
sodium borate, pH 8.5, and incubated overnight at room temperature. Prior to adding
cells, the wells were washed with PBS and Minimal Essential Media (MEM with 10%
FBS) was added until cells were ready for plating. Human fetal cerebral cortex
(E13-E16) was rinsed with Hank's Balanced Salt Solution (HBSS). Tissue was

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triturated in 1 mg of DNAse in HBSS. This suspension was filtered through a 100
micron nylon cell strainer and spun at 250 x g for 5 minutes. The cells were
resuspended in trypsin and incubated at 37°C for 20 minutes. Modified Minimal
Essential Media (MMEM with 10% FBS and 1 mg of DNase) was added and the cells
were resuspended; then collected again by centrifugation. Cells were resuspended in
MMEM containing B27, and plated in washed PEI-coated plates at 125,000 cells/well
in 96 well plates or at 2.5 million cells/well in 6 well plates. The human cortical
cultures (HCC) were incubated for 3 weeks with biweekly medium exchanges prior to
treatment.

Aβ generation

[0256] Aβ was generated by adding double distilled-water (ddH_2O) to Aβ to make up
a 1 mM stock. This was aged for 3 days at 37°C, aliquoted, and stored frozen at -
20°C. Soluble Aβ was made by adding DMSO to Aβ to make a 7.5 mM stock,
sonicating for 30 minutes, aliquoting, and freezing at -20°C. Neurotoxic Aβ was
generated by adding ddH_2O to Aβ, aliquoting, and freezing at -20°C.

Integrin immunoprecipitations from HCC lysates

[0257] HCC in 6 well plates were labeled with 100 μCi/ml ^{35}S-Methionine in
methionine-free medium overnight. Cells were washed, lysed with 25 mM Hepes, pH
7.5, 1% Triton X-100, 0.1 % SDS, 150 mM NaCl, 0.5 mM EDTA, 0.5 mM EGTA,
and passed through a 26 gauge needle three times. Insoluble material was removed
by centrifugation at 15,000 rpm for 15 minutes at 4°C. Lysates were pre-cleared on
rabbit anti-mouse (RAM) antibody coupled to protein A beads and
immunoprecipitated with integrin subunit-specific antibodies (Lia1/2 for β1, TS2/7
for α1, Gi9 for α2, P1B5 for α3, AN100226m for α4, Ab0771 for α5, GoH3 for α6,
Y9A2 for α9, and VNR147 for αv). Immunoprecipitates were washed 3 times with 1
ml of 25 mM Hepes, pH 7.5, 1% Triton X-100 150 mM NaCl, 0.5 mM EDTA, and
0.5 mM EGTA. Immunoprecipitated samples were separated on 8% tris-glycine gels
(Novex) and fixed; gels were dried, and the ^{35}S-labeled proteins in the gels were
visualized by autoradiography.

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Aβ immunofluorescence

[0258] HCC treated with Aβ for 72 hours were fixed with 4% paraformaldehyde, stained with 5μg/ml anti-Aβ-3D6-biotin, and visualized with 10μg/ml streptavidin-FITC (Jackson).

Aβ neurotoxicity in human cortical neurons

[0259] HCC were pretreated with antibodies or ligands for 30 minutes in neuronal medium (MEM) supplemented with glutamine and penicillin/streptomycin (basal media). One micromolar Aβ in basal medium was added for 1 hour. The medium was removed and the HCC were treated with antibodies or ligands and 20 μM soluble Aβ in basal medium for 3 days. At three days, the toxicity was determined by incubating in 10% alamar blue in basal medium for two hours. Fluorescence levels were measured relative to control and Aβ treated wells in triplicate.

Integrin heterodimer associations

[0260] HCC in 6-well plates in MMEM media supplemented with N-2 (Bottenstein's N-2 Formulation, e.g., Catalog #17502, Invitrogen Corp., Carlsbad, California) were placed on wet-ice, washed with PBS, lysed with 25 mM Hepes, pH 7.5, 1% Triton X-100, 0.1% SDS, 150 mM NaCl, 0.5 mM EDTA, and 0.5 mM EGTA, and passed through a 26 gauge needle 3 times. Insoluble material was removed by centrifugation at 15,000 rpm for 15 minutes at 4°C. Lysates were precleared on protein A beads and β1 integrin immunoprecipitated using anti-β1 integrin, Lia1/2 (Immunotech), and RAM/protein G beads (Pharmacia). Immunoprecipitates were washed 3 times with 1 ml of 25 mM Hepes, pH 7.5, 1 % Triton X-100 150 mM NaCl, 0.5 mM EDTA, and 0.5 mM EGTA. Immunoprecipitated samples were separated on 4-12% tris-glycine gels (Novex) and Western-blotted with anti-α2 integrin (AB 1936 from Chemicon) or with anti-αv integrin, MAB 1960 (Chemicon).

Aβ induction of paxillin phosphorylation

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[0261] Neurotoxic Aβ was added to HCC in 6-well plates in basal media
supplemented with N-2 for 0 minutes to 24 hours. HCC was placed on wet-ice,
washed with PBS, lysed with 25 mM Hepes, pH 7.5, 1% Triton X-100, 0.1% SDS,
150 mM NaCl, 0.5 mM EDTA, and 0.5 mM EGTA, and passed through a 26 gauge
needle 3 times. Insoluble material was removed by centrifugation at 15,000 rpm for
15 minutes at 4°C. Lysates were precleared on protein A beads and Fak or Pyk2
immunoprecipitated using anti-Fak (UBI) or anti-Pyk2 antibody (UBI), respectively,
and protein A beads. Immunoprecipitates were washed 3 times with 1 ml of 25 mM
Hepes, pH 7.5, 1% Triton X-100 150 mM NaCl, 0.5 mM EDTA, and 0.5 mM EGTA.
Immunoprecipitated samples were separated on 8% tris-glycine gels (Novex) and
Western blotted with anti-phosphotyrosine (RC20 from Transduction labs) and with
anti-paxillin (Transduction labs).

Example 1: Immunofluorescence pattern on human cortical neurons
[0262] The present examples produce an *in vitro* tissue culture model of Aβ plaques
that form on hippocampal and cortical neurons in Alzheimer's disease (AD) and
exhibit the associated neurotoxicity. The model uses primary human cortical neuronal
cultures to represent the neurons effected in AD as closely as possible. Addition of
Aβ to these cultures results in a reproducible Aβ meshwork that forms over 1-3 days
on the neurons and subsequently causes toxicity in the neurons. Aβ incubated on
plates without HCC also stained as a meshwork but consistently showed a more
uniform pattern with extensions that were shorter, thinner, and more linear than those
seen on HCC. Figs. 1A and 1B compare the meshwork in the presence and absence
of HCC.

Example 2: β1 integrin mediates Aβ meshwork and neurotoxicity
[0263] Because the meshwork resembled an extracellular matrix, like those formed
by integrin, it was investigated whether integrin was present in the HCC; and if so, if
integrin facilitated the Aβ meshwork formation on HCC. Gel electrophoresis showed
that β1 integrin is expressed in HCC. It was also found that β1 integrin blocking

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antibodies, including MAB1965, could block the Aβ meshwork pattern from forming on HCC (compare Fig. 2A (without antibody) to Fig. 2B (with antibody)). Whether the meshwork pattern was necessary for the toxicity generated by Aβ in these cultures was also investigated. To test this, HCC were incubated with β1 integrin blocking antibodies (AIIB2 and MAB1965) that had been shown to block the Aβ meshwork. These antibodies also blocked Aβ induced toxicity in a dose dependent manner (Fig. 2C). The antibody AIIB2 is a very potent blocker of Aβ toxicity, exhibiting an IC_{50} of 170 ng/ml or 1 nM. In contrast, a control antibody had no effect on toxicity.

Example 3: Agents that bind to α2 and αv integrins inhibit meshwork and
Aβ-mediated neurotoxicity

[0264] β1 integrin can pair with several α subunits to form different heterodimers. It was therefore tested which α integrin subunits were present in the HCC. The α2, α3, α4, α5, α6, and αv integrins were expressed in HCC. The α1 and α9 integrins were not expressed in HCC. Inhibitory antibodies against all these alpha integrin subunits were tested for their ability to inhibit Aβ meshwork formation and to inhibit its neurotoxicity. Inhibitory antibodies to α2 and αv inhibited Aβ meshwork formation (Fig. 3A). These antibodies also inhibited Aβ's neurotoxic effect in HCC (Fig. 3B). To show specificity to these particular integrins, 2-3 inhibitory antibodies were tested against each of these integrins and against the other integrin subunits as well. A very clear specificity to α1, α2, and αv integrins, mediating both the meshwork formation and neurotoxicity, was found (Table 1).

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Table 1: Aβ meshwork and neurotoxicity inhibition with integrin
blocking antibodies and ligands

Antibody:	Meshwork Inhibition	Maximal inhibition of toxicity (%)
β1 integrin:		
AIIB2	ND	100
1965	Yes	100
Lia1/2	Yes	80
TS2/16 (activating)	ND	0
α1 integrin:		
TS2/7	ND	5
1973Z	ND	6
α2 integrin:		
Gi9	Yes	100
1950Z	Yes	100
1998	ND	25
α3 integrin:		
1952Z	ND	10
2056	ND	10
2057	ND	20
α4 integrin:		
AN100226m	ND	10
α5 integrin:		
P1D6	ND	5
SAM1	No	5
α6 integrin:		
GoH3	ND	40
α9 integrin:		
Y9A2	No	0
αv integrin:		
VNR147	Yes	100
1980	Yes	40
IM1603	ND	20
Fibronectin	Yes	32
Superfibronectin	Yes	100
Laminin	ND	20
NCAM antibody	No??	0

[0265] A weak but reproducible effect of an anti-α6 antibody on toxicity was
observed. Finally, to confirm that these effects were directed against the integrins and

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not nonspecifically interfering with Aβ polymerization, Aβ toxicity was analyzed side-by-side in human and mouse cortical cultures. The antibodies used in these assays do not crossreact with mouse integrins. The anti-human integrin antibodies could inhibit Aβ toxicity in human cultures but not in mouse cultures, suggesting that the antibodies were not nonspecifically interacting with Aβ to inhibit toxicity. It was confirmed that α2 and αv were associated with β1 integrin in HCC cells by immunoprecipitating HCC lysates with a β1 antibody and then blotting the precipitated material with antibodies for α2 and αv. These results indicate that heterodimers of α2β1 and αvβ1 are functional mediators of Aβ meshwork formation and neurotoxicity.

Example 4: Fibronectin and anti-laminin antibodies inhibit Aβ meshwork formation and neurotoxicity

[0266] Other components of the integrin/extracellular meshwork were investigated for involvement in mediating Aβ meshwork formation and neurotoxicity. These other components included the αvβ1 integrin ligands, fibronectin, and superfibronectin (multimers of fibronectin domain forming a meshwork), and the α2β1 ligands, collagen and laminin. Laminin has two chains β1 and γ1, both of which are elevated in Alzheimer's disease plaques (Murtomaki *et al., J. Neur. Res.*, 32:261-73 (1992)). Fibronectin and superfibronectin were capable of inhibiting Aβ meshwork formation and neurotoxicity (Table 1). This result can be explained by fibronectin competing with Aβ for effects on αvβ1 function. In contrast, an αvβ1 ligand, laminin, was not capable of inhibiting Aβ meshwork or neurotoxicity (Table 1). To determine why an αvβ1 ligand was protective, when an αvβ1 ligand was not, anti-laminin antibodies were tested in the meshwork formation and neurotoxicity assay. Two laminin antibodies were highly protective both in Aβ meshwork formation (Fig. 5A) and Aβ mediated neurotoxicity (Fig. 5B). The anti-laminin antibody #AB19012 showed an IC_{50} of less than 1 nM. In contrast, anti-collagen antibodies, had no effect on Aβ meshwork formation and neurotoxicity (Fig. 5C).

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Example 5: Aβ activates paxillin tyrosine phosphorylation, an early event in integrin signaling pathways

[0267] Integrin activation by an extracellular matrix ligand leads to the activation of focal adhesion kinases, such as Fak, and tyrosine phosphorylation of its substrate, paxillin. To determine if Aβ was similarly stimulating integrin signaling pathways, the tyrosine phosphorylation pattern of Fak-associated paxillin upon Aβ addition to HCC (Fig. 6A) was analyzed. Consistent activation of Fak-associated paxillin tyrosine phosphorylation was not found. However, a consistent increase in Pyk2-associated paxillin tyrosine phosphorylation subsequent to Aβ stimulation was observed. Pyk2 is also a focal adhesion kinase and may be mediating an aberrant Aβ/integrin signaling pathway that leads to neurotoxicity (Fig. 6B). The activation of Pyk2-, rather than Fak-associated paxillin tyrosine phosphorylation, may be what causes a toxic response in these conditions. In any case, Aβ activates paxillin tyrosine phosphorylation, an early event in integrin signaling pathways, indicating that the Aβ neurotoxic signal may be mediated through direct engagement of the $\alpha 2\beta 1$ and $\alpha v\beta 1$ integrin signaling pathways.

Example 6: Amylin Two Component Toxicity

[0268] Seed or aggregated amylin (1 mM) from CPR, Inc. (641-80, lot NG-0213) was made by adding 200 μl water/mg powder and then aging the solution for three days at 37°C. Soluble amylin (5 mM) was prepared by adding 40 μl DMSO/mg powder and sonicating the mixture for 30 minutes in a water bath. Both stock solutions were aliquoted and frozen until ready for use. Soluble amylin stock was diluted to 20 μM in culture medium just prior to use and filtered through an Amicon 30 filter that had been pre-washed with water. Filtered material was then diluted to its appropriate concentration.

[0269] Human cortical neurons (at 125,000 cells/96 well) were treated for 1 hour with seed amylin at 5 μM, 100 μl/well. Cells were aspirated and soluble amylin was

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added back at 5 µM per 100 µl/well. For compound studies, 50 µl of 2X compound was added before adding the soluble amylin.

[0270] Fig. 6 demonstrates toxicity after 1 day when the human cortical neurons were seeded for 1 hour followed by aspiration and treatment with soluble amylin. Integrin antibodies were added to the cells in the presence of the seed and soluble amylin to inhibit toxicity. Fig. 7 demonstrates that some integrin antibodies, namely 2034 anti-laminin, 1965 anti-β1 integrin, 1958 anti- αv (VNR) and 1950 anti- α2, protected the cells against the toxicity of the amylin two components. Fig. 8 demonstrates that amylin two component toxicity is further inhibited by additional integrin antibodies including anti-αvβ3 and anti-αv; and cytochalasin D.

[0271] All publications and patent applications cited above are incorporated by reference in their entirety for all purposes to the same extent as if each individual publication or patent application were specifically and individually indicated to be so incorporated by reference. Although the present invention has been described in some detail by way of illustration and example for purposes of clarity and understanding, it will be apparent that certain changes and modifications may be practiced within the scope of the appended claims.

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CLAIMS

What is claimed is:

1.   A method of inhibiting formation of an amyloid deposit comprising administering an effective dosage of one or more agents that bind to a molecule selected from among:

        a) an integrin subunit selected from among $\alpha2$, αv, $\alpha6$, and $\beta1$;

        b) an integrin selected from among $\alpha2\beta1$, $\alpha6\beta1$, and $\alpha v\beta1$; and

        c) laminin;

under conditions such that the one or more agents inhibit the formation of an amyloid deposit.

2.   The method of claim 1, wherein the agent binds to the $\alpha2$ integrin subunit.

3.   The method of claim 1, wherein the agent binds to the αv integrin subunit.

4.   The method of claim 1, wherein the agent binds to the $\beta1$ integrin subunit.

5.   The method of claim 1, wherein the agent binds to the $\alpha6$ integrin subunit.

6.   The method of claim 1, wherein the agent binds to the integrin $\alpha2\beta1$.

7.   The method of claim 1, wherein the agent binds to the integrin $\alpha v\beta1$.

8.   The method of claim 1, wherein the agent binds to the integrin $\alpha6\beta1$.

9.   The method of claim 1, wherein the agent binds to laminin.

10.   The method of claim 1, wherein effective dosages of at least two agents that bind to at least two integrin subunits selected from among $\alpha2$, $\alpha6$, αv, and $\beta1$ are administered.

11.   The method of claim 1, wherein effective dosages of at least three agents that bind to at least three integrin subunits selected from among $\alpha2$, $\alpha6$, αv, and $\beta1$ are administered.

12.   The method of claim 1, wherein effective dosages of at least four agents that bind to the integrin subunits $\alpha2$, $\alpha6$, αv, and $\beta1$ are administered.

13.   The method of claim 1, wherein the agent is a peptide comprising an RGD (Arg-Gly-Asp) motif.

14.   The method of claim 1, wherein the agent is a ligand of $\alpha v\beta1$, $\alpha6\beta1$, or $\alpha2\beta1$ integrins.

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15.   The method of claim 1, wherein the agent is fibronectin or superfibronectin.

16.   The method of claim 1, wherein the agent inhibits adhesion of α2 integrin subunit-expressing cells to collagen.

17.   The method of claim 1, wherein the agent inhibits adhesion of αv integrin subunit-expressing cells to vitronectin or fibronectin.

18.   The method of claim 1, wherein the agent inhibits adhesion of β1 integrin subunit-expressing cells to fibronectin.

19.   The method of claim 1, wherein the agent inhibits adhesion of αv integrin subunit-expressing cells to osteopontin.

20.   The method of claim 1, wherein the agent inhibits adhesion of α6 integrin subunit-expressing cells to osteopontin.

21.   The method of claim 1, wherein the agent is a monoclonal or polyclonal antibody.

22.   The method of claim 1, wherein the agent is an antibody that recognizes the same epitope as an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

23.   The method of claim 1, wherein the agent is an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

24.   The method of claim 1, wherein the agent competes for binding to the integrin α2β1 or αvβ1 with an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

25.   The method of claim 1, wherein the agent is a human antibody.

26.   The method of claim 1, wherein the agent is a humanized antibody.

27.   The method of claim 1, wherein the agent is a mouse antibody.

28.   The method of claim 1, wherein the agent is a polyclonal antibody.

29.   The method of claim 1, wherein the agent is a monoclonal antibody.

30.   The method of claim 1, wherein the agent is an antibody fragment.

31.   The method of claim 1, wherein the agent comprises one or more heavy chains, light chains, F(ab), F(ab)₂, F(ab)ₑ, or F(v) of an antibody.

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32.   The method of claim 1, wherein the agent is an antibody and the isotype of the antibody is IgG1 or IgG4.

33.   The method of claim 1, wherein the agent is an antibody and the isotype of the antibody is IgG2 or IgG3.

34.   The method of claim 1, wherein the agent is an antibody chain.

35.   The method of claim 1, wherein the agent is an antibody and the antibody comprises two pairs of light and heavy chains.

36.   The method of claim 1, wherein the agent is administered to a patient.

37.   The method of claim 36, wherein the agent is an antibody and the dosage of the antibody is about 0.01 to about 10 mg/kg body weight of the patient.

38.   The method of claim 36, wherein the agent is administered with a carrier as a pharmaceutical composition.

39.   The method of claim 36, wherein the agent is administered intraperitoneally, orally, intranasally, subcutaneously, intrathecally, intramuscularly, topically or intravenously.

40.   The method of claim 36, wherein the patient is suffering from an amyloidogenic disease.

41.   The method of claim 40, wherein the disease is Alzheimer's disease.

42.   The method of claim 40, wherein the disease is type II diabetes.

43.   The method of claim 40, wherein the disease is Parkinson's disease.

44.   The method of claim 40, wherein the disease is caused all or in part by prion infection.

45.   The method of claim 40, wherein the disease is an amyloidosis.

46.   The method of claim 40, wherein the disease is hereditary or systemic amyloidosis.

47.   The method of claim 40, wherein the disease is Down's syndrome.

48.   The method of claim 1, wherein a nucleic acid is administered that encodes the agent.

49.   The method of claim 1, wherein the agent is an antisense RNA molecule, an antisense DNA molecule, a ribozyme, RNAi, or a zinc-finger protein.

50.   A method of inhibiting amyloid toxicity comprising administering an effective
dosage of one or more agents that bind to a molecule selected from among:

      a) an integrin subunit selected from among $\alpha 2$, αv, $\alpha 6$, and $\beta 1$;

      b) an integrin selected from among $\alpha 2\beta 1$, $\alpha 6\beta 1$, and $\alpha v\beta 1$; and

      c) laminin;

under conditions such that the one or more agents inhibit amyloid toxicity.

51.   The method of claim 50, wherein the agent binds to the $\alpha 2$ integrin subunit.

52.   The method of claim 50, wherein the agent binds to the αv integrin subunit.

53.   The method of claim 50, wherein the agent binds to the $\beta 1$ integrin subunit.

54.   The method of claim 50, wherein the agent binds to the $\alpha 6$ integrin subunit.

55.   The method of claim 50, wherein the agent binds to the integrin $\alpha 2\beta 1$.

56.   The method of claim 50, wherein the agent binds to the integrin $\alpha v\beta 1$.

57.   The method of claim 50, wherein the agent binds to the integrin $\alpha 6\beta 1$.

58.   The method of claim 50, wherein the agent binds to laminin.

59.   The method of claim 50, wherein effective dosages of at least two agents that
bind to at least two integrin subunits selected from among $\alpha 2$, $\alpha 6$, αv, and $\beta 1$ are
administered.

60.   The method of claim 50, wherein effective dosages of at least three agents that
bind to at least three integrin subunits selected from among $\alpha 2$, $\alpha 6$, αv, and $\beta 1$ are
administered.

61.   The method of claim 50, wherein effective dosages of at least four agents that
bind to the integrin subunits $\alpha 2$, $\alpha 6$, αv, and $\beta 1$ are administered.

62.   The method of claim 50, wherein the agent is a peptide comprising an RGD
(Arg-Gly-Asp) motif.

63.   The method of claim 50, wherein the agent is a ligand of $\alpha v\beta 1$, $\alpha 6\beta 1$, or $\alpha 2\beta 1$
integrins.

64.   The method of claim 50, wherein the agent is fibronectin or superfibronectin.

65.   The method of claim 50, wherein the agent inhibits adhesion of $\alpha 2$ integrin
subunit-expressing cells to collagen.

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66.   The method of claim 50, wherein the agent inhibits adhesion of αv integrin subunit-expressing cells to vitronectin or fibronectin.

67.   The method of claim 50, wherein the agent inhibits adhesion of β1 integrin subunit-expressing cells to fibronectin.

68.   The method of claim 50, wherein the agent inhibits adhesion of αv integrin subunit-expressing cells to osteopontin.

69.   The method of claim 50, wherein the agent inhibits adhesion of α6 integrin subunit-expressing cells to osteopontin.

70.   The method of claim 50, wherein the agent is a monoclonal or polyclonal antibody.

71.   The method of claim 50, wherein the agent is an antibody that recognizes the same epitope as an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

72.   The method of claim 50, wherein the agent is an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

73.   The method of claim 50, wherein the agent competes for binding to the integrin α2β1 or αvβ1 with an antibody selected from among 1965, Lia1/2, Gi9, 1950Z, VNR147, and 1980.

74.   The method of claim 50, wherein the agent is a human antibody.

75.   The method of claim 50, wherein the agent is a humanized antibody.

76.   The method of claim 50, wherein the agent is a mouse antibody.

77.   The method of claim 50, wherein the agent is a polyclonal antibody.

78.   The method of claim 50, wherein the agent is a monoclonal antibody.

79.   The method of claim 50, wherein the agent is an antibody fragment.

80.   The method of claim 50, wherein the agent comprises one or more heavy chains, light chains, F(ab), F(ab)$_2$, F(ab)$_c$, or F(v) of an antibody.

81.   The method of claim 50, wherein the agent is an antibody and the isotype of the antibody is IgG1 or IgG4.

82.   The method of claim 50, wherein the agent is an antibody and the isotype of the antibody is IgG2 or IgG3.

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83.   The method of claim 50, wherein the agent is an antibody chain.

84.   The method of claim 50, wherein the agent is an antibody and the antibody comprises two pairs of light and heavy chains.

85.   The method of claim 50, wherein the agent is administered to a patient.

86.   The method of claim 85, wherein the agent is an antibody and the dosage of the antibody is about 0.01 to about 10 mg/kg body weight of the patient.

87.   The method of claim 85, wherein the agent is administered with a carrier as a pharmaceutical composition.

88.   The method of claim 85, wherein the agent is administered intraperitoneally, orally, intranasally, subcutaneously, intrathecally, intramuscularly, topically or intravenously.

89.   The method of claim 85, wherein the patient is suffering from an amyloidogenic disease.

90.   The method of claim 89, wherein the disease is Alzheimer's disease.

91.   The method of claim 89, wherein the disease is type II diabetes.

92.   The method of claim 89, wherein the disease is Parkinson's disease.

93.   The method of claim 89, wherein the disease is caused all or in part by prion infection.

94.   The method of claim 89, wherein the disease is an amyloidosis.

95.   The method of claim 89, wherein the disease is hereditary or systemic amyloidosis.

96.   The method of claim 89, wherein the disease is Down's syndrome.

97.   The method of claim 50, wherein a nucleic acid is administered that encodes the agent.

98.   The method of claim 50, wherein the agent is an antisense RNA molecule, an antisense DNA molecule, a ribozyme, RNAi, or a zinc-finger protein.

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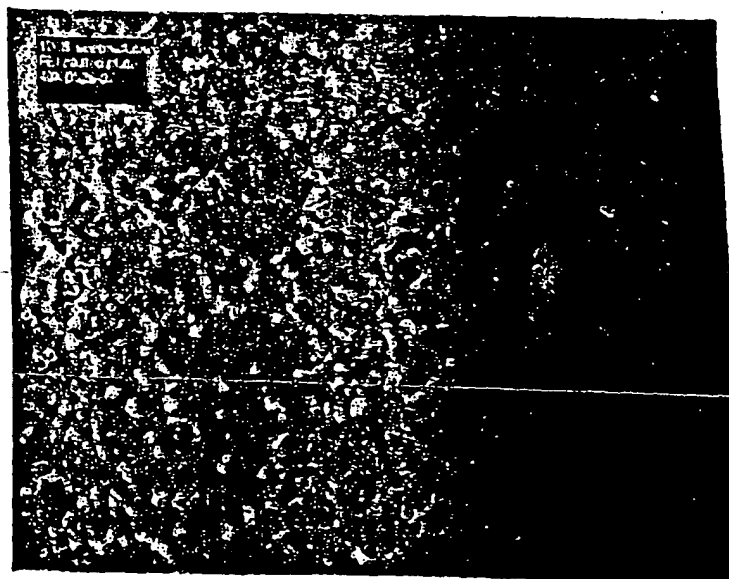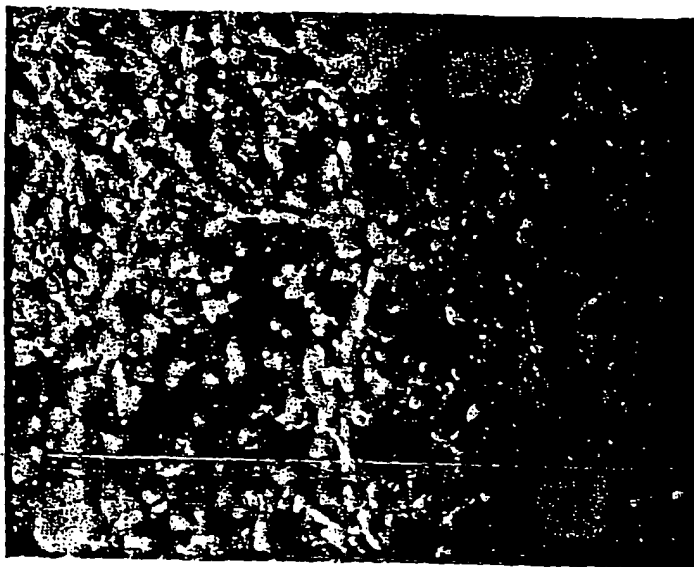
Figure 2A:

β1 Integrin Ip

Figure 2B:

Figure 2C:

Figure 3A:

250 →

98 →

64 →

50 →

36 →

} Integrin subunits

(−) α1 α2 α3 α4 α5 (−) α6 α9 αv
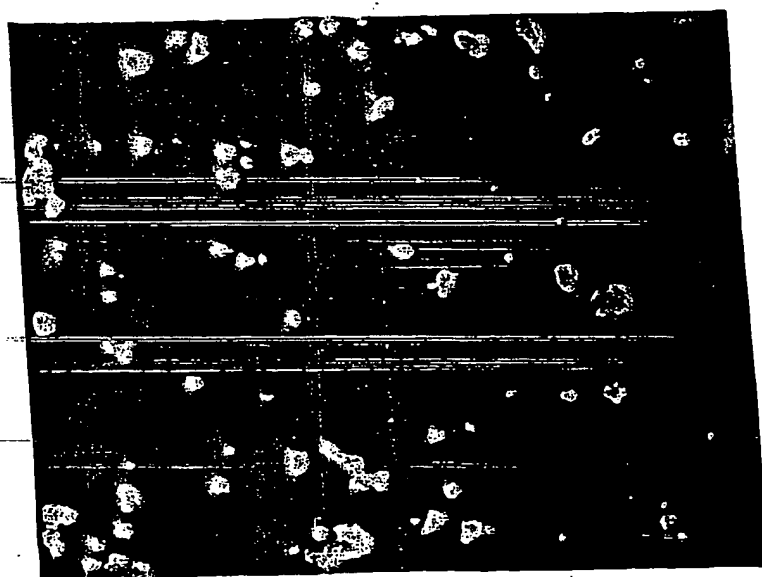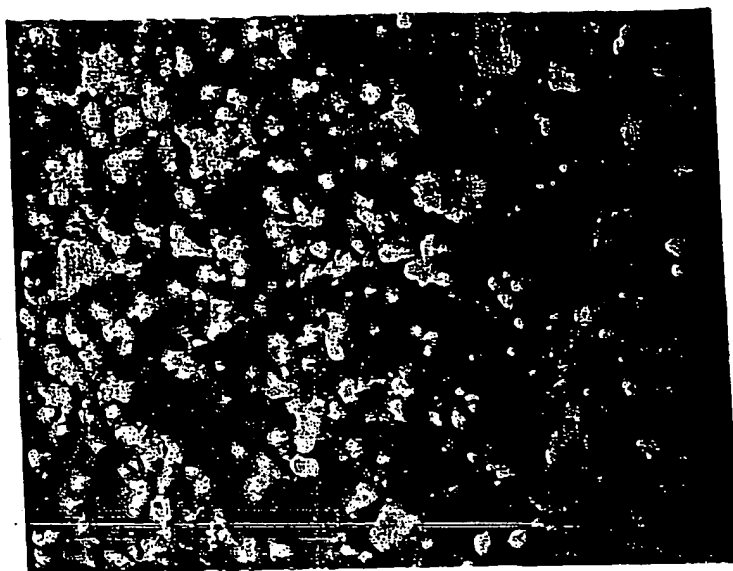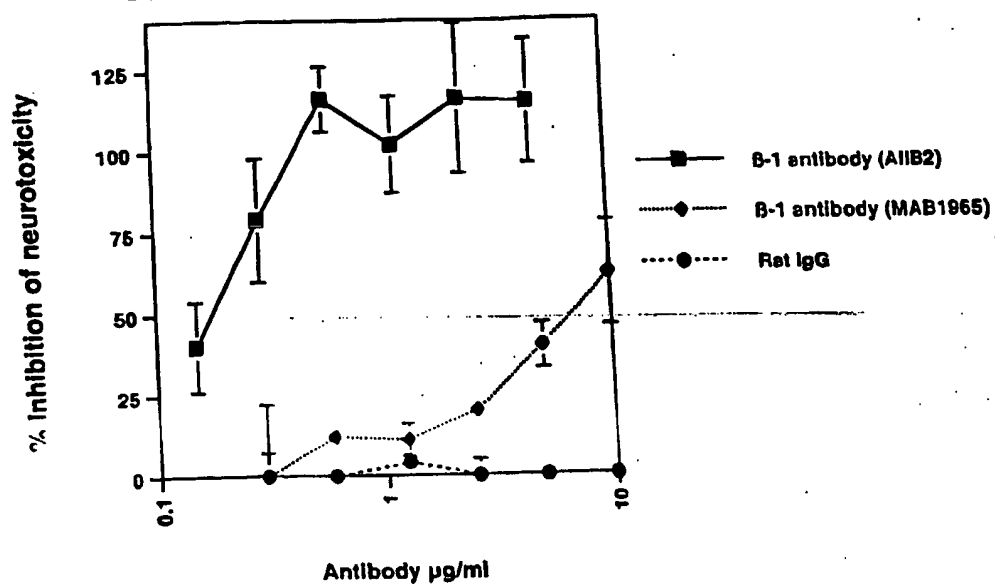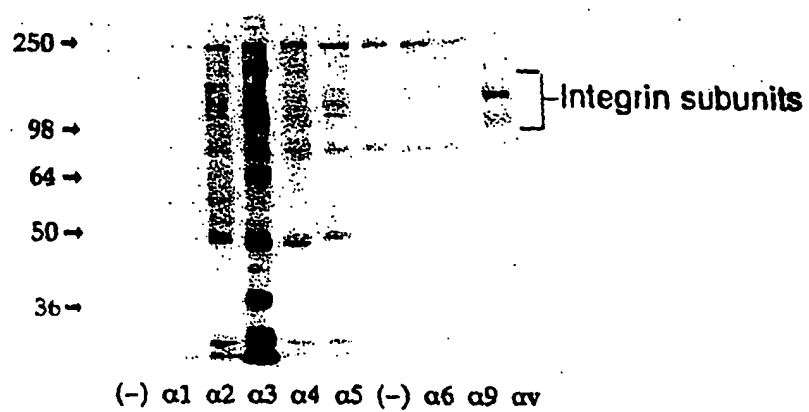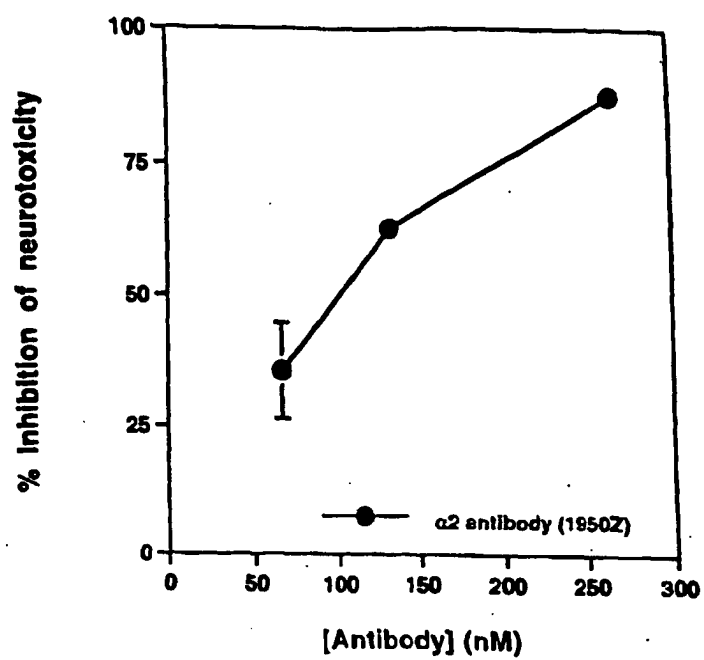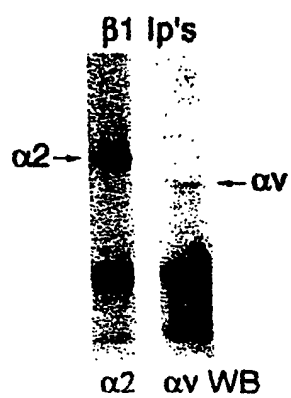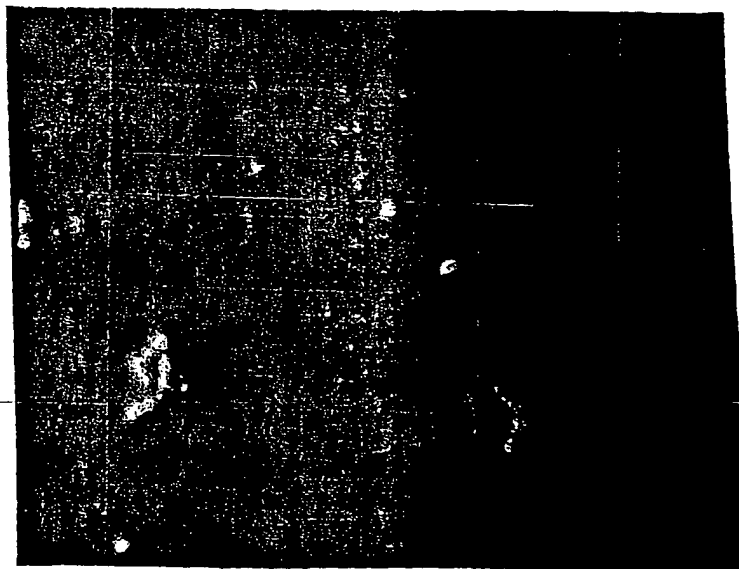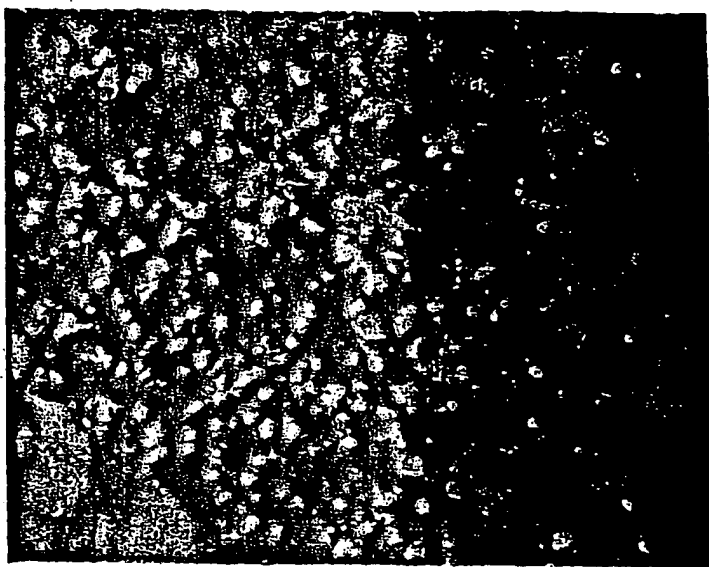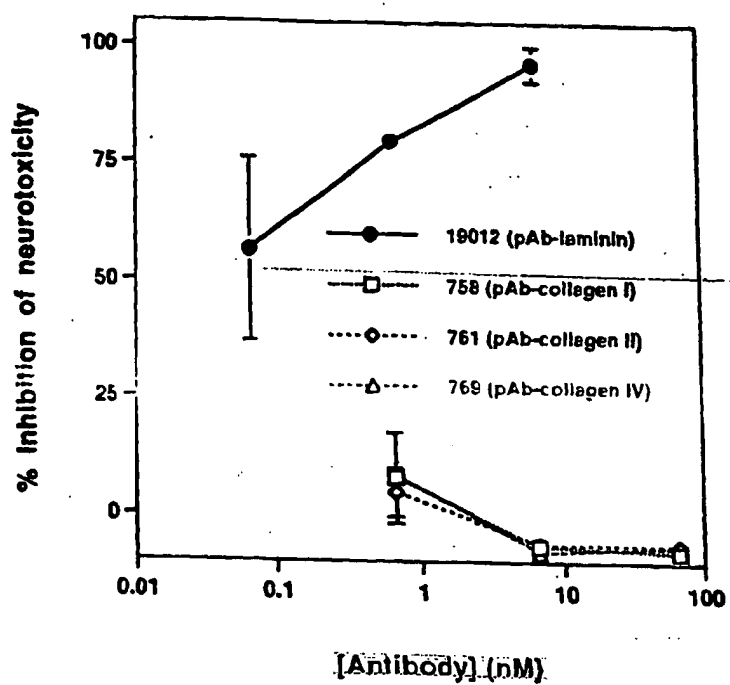
Figure 3B:

Figure 3C:

Figure 4

β1 Ip's

α2→

←αv

α2 αv WB
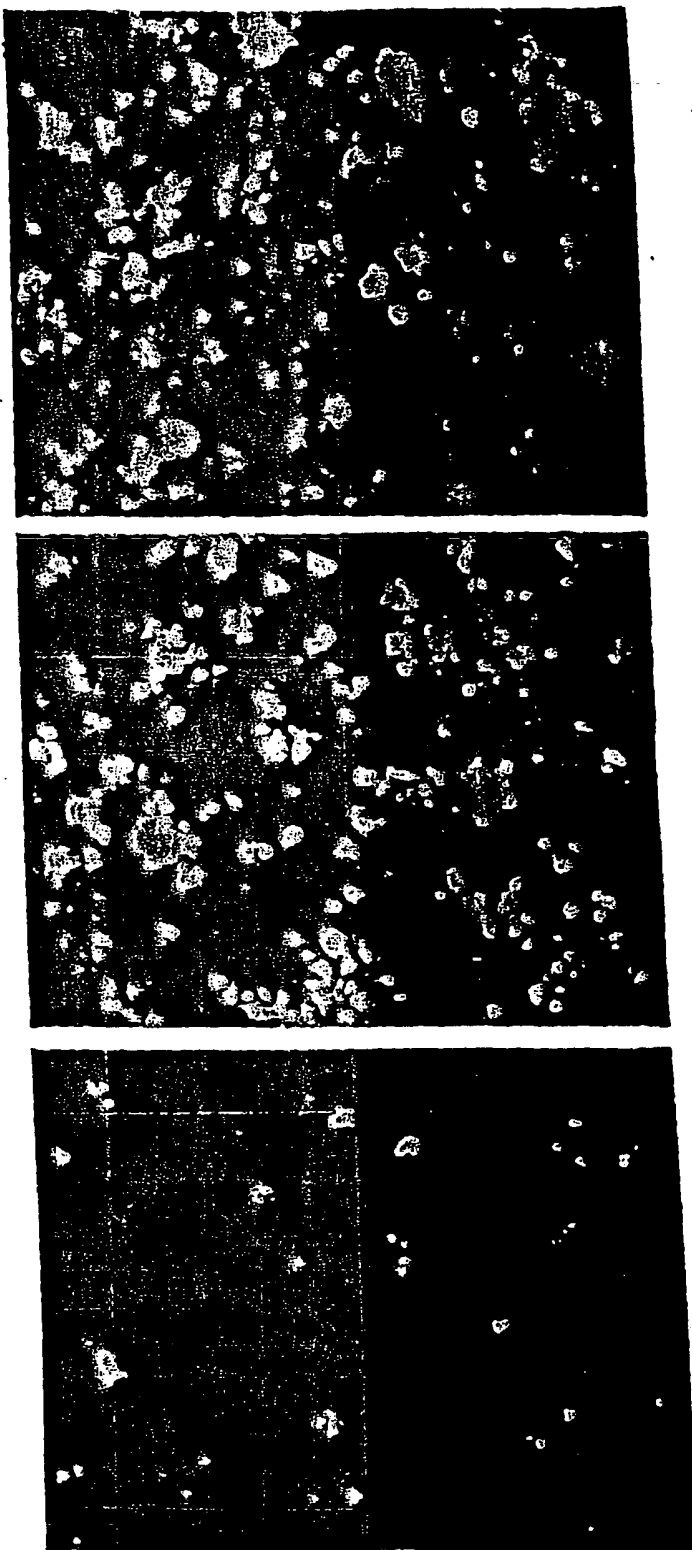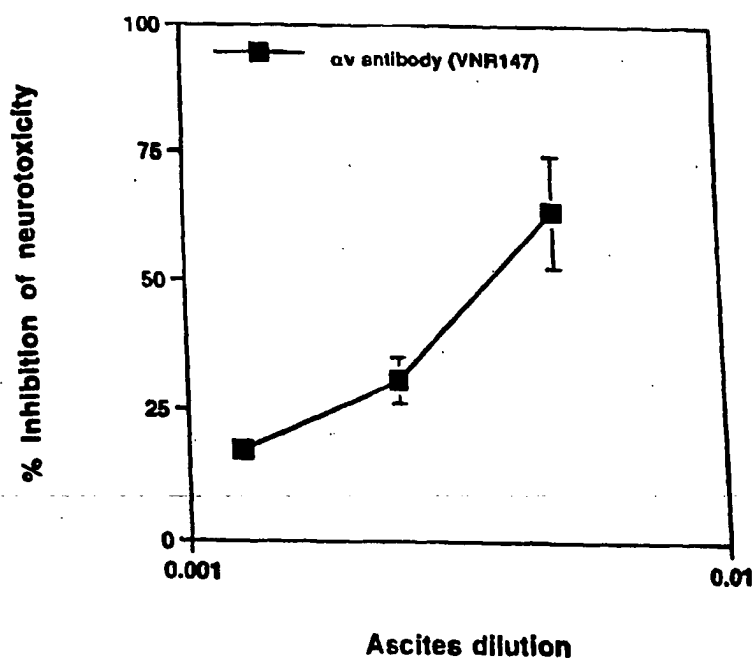
Figure 5A:

Figure 5B:

Figure 5C:

Figure 6A:

Aβ treatment: 0 5min 1   21   24   27 hrs

Figure 6 B:

AB treatment: 0 5min 1 21 24 27 hours

HCC treated with seed amylin (1mM H2O stock aged 3d), soluble amylin (5 mM DMSO stock sonicated), or a titration of seed amylin for 1h + 5 uM soluble amylin 2DOT 071201

FIGURE 7

% Inhibition of amylin 2 component toxicity
HCC 1DOT (5 uM seed amylin 1h, 5 uM soluble
amylin) 071901

2034 anti-laminin
1965 anti-ß1 integrin
1958 anti-alpha v (VNR)
1950 anti-alpha 2

FIGURE 8

% Inhibition of amylin 2 component toxicity
HCC 1DOT (5 uM seed amylin 1h, 5 uM soluble amylin) 080101

FIGURE 9A

% Inhibition of amylin 2 component toxicity
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amylin) 080101
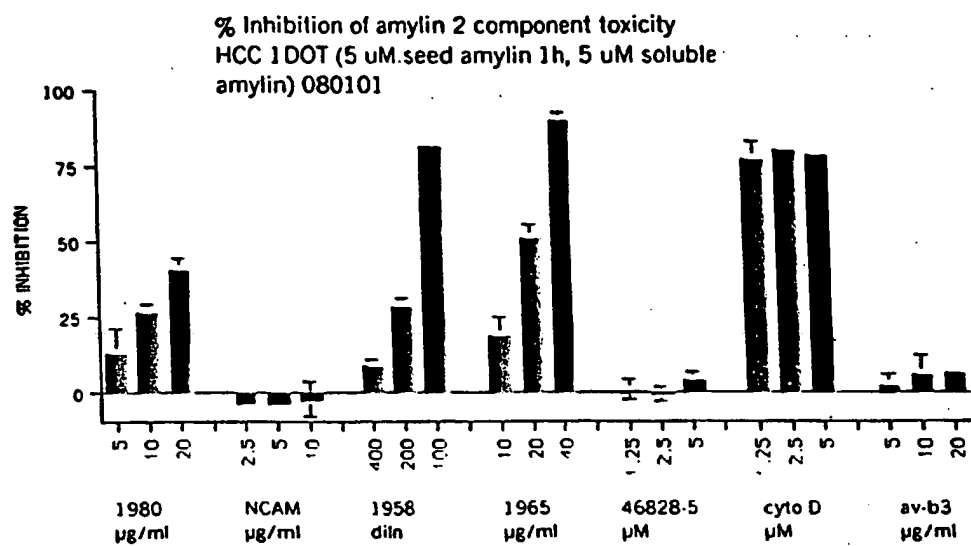
FIGURE 9E

SEQUENCE LISTING

<110> Griswold Prenner, Irene

       Wright, Sarah

       Yednock, Theodore

       Rydel, Russell

<120> Methods of Inhibiting Amyloid Toxicity

<130> 08576.0030-00

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<141> Filed Herewith

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Gly Leu Met Val Gly Gly Val Val Ile Ala
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                    20   25   30

        Gly Leu Met Val Gly Gly Val
                35